THE SOUTH AFRICAN JOURNAL OF SCIENCE

VOLUME XLII

BEING THE

REPORT

OF THE

FORTY-THIRD ANNUAL MEETING

OF THE

SOUTH AFRICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

JOHANNESBURG

1945

2nd, 3rd and 4th JULY

JOHANNESBURG
PUBLISHED BY THE ASSOCIATION
and
Printed by RADFORD, ADLINGTON, LTD., Rissik and Marshall Streets,
Johannesburg, South Africa

1946

DIE

SUID-AFRIKAANSE JOURNAL VAN WETENSKAP

DEEL XLII

SYNDE DIE

VERSLAG

VAN DIE

DRIE-EN-VEERTIGSTE JAARVERGADERING

VAN DIE

SUID-AFRIKAANSE GENOOTSKAP

VIR DIE

BEVORDERING VAN WETENSKAP

JOHANNESBURG

1945

2 3, en 4 JULIE

JOHANNESBURG:
UITGEGEE DEUR DIE GENOOTSKAP
en
Gedruk deur RADFORD, ADLINGTON, BPK., Rissik-en Marshallstraat,
Johannesburg, Suid-Afrika

1946

CONTENTS.

THE

SOUTH AFRICAN JOURNAL OF SCIENCE

BEING THE REPORT OF THE

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

(1945, JOHANNESBURG)

Vol. XLII — **JUNE, 1946** — **Vol. XLII**

EDITORIAL NOTE.

Our experience during the last year has made it necessary to call the attention of the members who provide the scientific papers for reading at the Annual Meeting and for publication in this Journal, to the terms of our constitution regulating these contributions. By-law No. 64 reads: "Papers should be **condensed and limited**, as far as possible, **to the description or discussion of new facts, new observations or new ideas.**" Last year 42 papers were read before the Association, but one-third of their number could only be published in abstract or in title, an unpleasing necessity which, although due in part to the disparity between the pre-war standard of the Association's income and post-war costs, could have been largely avoided by more consideration of the by-law.

Hon. Associate Editor.

OFFICERS AND COUNCIL FOR 1945-46
AMPSDRAERS EN RAAD VIR 1945-46

PATRON:
HIS MAJESTY THE KING.

President: Dr. the Hon. F. E. T. KRAUSE, P.O. Box 1363, Pretoria.

Past President: Mr. E. C. CHUBB, The Museum, Durban.

Vice-Presidents:
Dr. G. de Kock, Veterinary Laboratory, Onderstepoort; Dr. S. H. Skaife, P.O. Box 15, Cape Town; Dr. H. H. Dodds, Sugar Experimental Station, Mount Edgecombe, Natal; Mr. F. W. Storey, P.O. Box 194, Bloemfontein.

Hon. General Secretaries:
Prof. H. H. Paine, The University, Johannesburg; Mr. Reay H. N. Smithers, P.O. Dynamite Factory, C.P.

Hon. General Treasurer: Mr. Jas. Gray, P.O. Box 5254, Johannesburg.

Hon. Editor of Publications: Prof. John Phillips, The University, Johannesburg.

Hon. Associate Editor: Mr. S. B. Asher, 51 Fortescue Road, Yeoville, Johannesburg.

Hon. Librarian: Mr. P. Freer, The University, Johannesburg.

Assistant General Secretaries:
The Associated Scientific and Technical Societies of South Africa, Kelvin House, P.O. Box 6894, Johannesburg.

Ordinary Members of Council:

TRANSVAAL

Witwatersrand

Mr. S. B. Asher
Dr. A. E. H. Bleksley
Mr. R. Craib
Dr. F. W. Fox
Dr. A. Galloway
Dr. T. D. Hall
Prof. P. R. Kirby
Mr. A. J. Limebeer
Prof. I. D. MacCrone
Prof. L. F. Maingard
Dr. G. Martinaglia
Prof. John Orr
Mr. F. R. Paver
Dr. J. B. Robertson
Prof. G. H. Stanley
Prof. C. van Riet Lowe
Dr. L. H. Wells
Mr. H. Wilson

Pretoria

Dr. P. J. du Toit
Dr. R. A. Dyer
Dr. M. G. Mes
Dr. E. Percy Phillips
Dr. A. Pijper
Dr. J. I. Quin.

Outside Districts

Prof. A. P. G. Goossens

NATAL

Durban and District

Mr. F. G. Braithwaite
Mr. E. B. Dunkerton
Mr. J. F. Schofield

Pietermaritzburg and Outlying Districts

Prof. A. W. Bayer
Prof. S. F. Bush

PROVINCE OF THE CAPE OF GOOD HOPE

Cape Town

Lt.-Col. C. Graham Botha
Dr. A. L. du Toit
Mr. L. de Kock
Mr. George W. Lyon
Mr. D. R. Macfarlane.
Col. J. G. Rose

Stellenbosch and District

Mr. F. J. S. Anders
Prof. C. G. S. de Villiers

East London and Port Elizabeth

Mr. H. C. Gardham

Grahamstown, Kingwilliamstown and District

Prof. J. Omer-Cooper

Kimberley

Mr. J. H. Power

Oudtshoorn

Dr. M. Boehmke

Outside Districts

. . . .

ORANGE FREE STATE

Bloemfontein

Dr. E. C. N. van Hoepen

SOUTHERN RHODESIA

. . . .

Trustees:

Endowment Fund

Mr. A. V. H. Carter
Prof. L. Crawford
Prof. John Orr

South Africa and British Association Medal Funds

Hon. J. H. Hofmeyr
Prof. L. F. Maingard

Publications Committee:
Prof. John Phillips (Hon. Editor), Chairman, Dr. F. E. T. Krause (President), Dr. G. de Kock (Vice-President), Mr. S. B. Asher (Hon. Associate Editor), Dr. A. E. H. Bleksley, Mr. P. Freer, Mr. Jas. Gray, Dr. T. D. Hall, Prof. L. F. Maingard, Prof. H. H. Paine, Mr. F. R. Paver, Prof. G. H. Stanley.

PROCEEDINGS OF THE FORTY-THIRD ANNUAL GENERAL MEETING OF MEMBERS HELD AT KELVIN HOUSE, JOHANNESBURG, ON WEDNESDAY, 4th JULY, 1945 AT 11 A.M.

VERRIGTINGS VAN DIE DRIE-EN-VEERTIGSTE ALGEMENE JAARVERGADERING VAN LEDE IN KELVIN-HUIS, JOHANNESBURG, OM ELF UUR OP WOENSDAG, 4 JULIE, 1945, GEHOU.

Present / Teenwoordig. — Mr. / Mnr. E. C. Chubb (President / Voorsitter), Mr./Mnr. S. B. Asher, Miss/Mej. A. I. Bailey, Dr. A. E. H. Bleksley, Mr./Mnr. W. S. F. Cameron, Mrs./Mev. G. E. Chubb, Miss/Mej. A. F. Cloete, Mr./Mnr. C. Cohen, Mr./Mnr. R. Craib, Mrs./Mev. L. E. Davidson, Dr. H. H. Dodds, Dr. A. L. du Toit, Dr. R. A. Dyer, Mr./Mnr. C. Ferguson, Dr. V. F. Fitzsimons, Mr./Mnr. K. Flegg, Dr. F. W. Fox, Mr./Mnr. P. Freer, Mr./Mnr. D. H. G. Gouveia, Mrs./Mev. J. V. N. Gouveia, Mr./Mnr. D. J. S. Gray, Mr./Mnr. Jas. Gray, Miss/Mej. V. C. Green, Prof. J. M. Hector. Dr. A. J. T. Janse, Mrs./Mev. R. G. Knight, Dr. F. E. T. Krause, Prof. W. J. Lütjeharms, Prof. I. D. McCrone, Prof. L. F. Maingard, Mr./Mnr. B. D. Malan, Dr. A. McMartin, Mr./Mnr. B. T. Mennell, Dr. D. B. D. Meredith, Dr. Margaretha G. Mes, Mr./Mnr. A. O. D. Mogg, Dr. A. G. Oettle, Prof. John Orr, Dr. R. J. Ortlepp, Dr. E. Percy Phillips, Prof, John Phillips, Dr. A. Pijper, Dr. E. S. Priester, Dr. J. I. Quin, Prof. A. Quintanilha, Rev./Eerw. Noel Roberts, Dr. B. F. J. Schonland, Prof. G. H. Stanley, Dr. H. van Gent, Prof. C. van Riet Lowe, Dr. G. van Son, Prof. F. L. Warren, Prof. J. H. Wellington, Dr. L. H. Wells, Miss/Mej. E. E. Wijers, Dr. H. E. Wood, Mrs./Mev. M. E. Wood, Prof. H. H. Paine (Honorary General Secretary/Ere-algemene Sekretaris), and Mr./Mnr. A. J. Adams (Assistant General Secretary/Assistent-algemene Sekretaris).

Minutes.—The Minutes of the Forty-second Annual General Meeting, held at Johannesburg on the 4th July, 1944, and printed on pages iii to vi of the Report of the Johannesburg Session (Volume XLI of the Journal) were confirmed.

Notule.—Die Notule van die Twee-en-veertigste Algemene Jaarvergardering, gehou in Johannesburg op 4 Julie 1944 en gedruk op bladsye iii tot vi van die verslag van die Johannesburgse Byeenkoms (Deel XLI van die Journal) is goedgekeur.

2. **Greetings and Apologies.**—The Honorary General Secretary reported that a message for a successful meeting had been received from Prof. A. W. Bayer.

Groete en Verontskuldigings.—Die Ere-algemene Sekretaris het gerapporteer dat beste wense vir 'n suksesvolle vergadering ontvang is van Prof. A. W. Bayer.

It was noted that apologies for absence had been received from:

Ontvange verontskuldigings vir afwesigheid is genoteer van:

Mr. H. B. S. Cooke, Dr. T. D. Hall, Mr. F. E. Gordon Helps, Dr. P. A. E. Kamerman, Prof. P. R. Kirby, Mr. A. J. Limebeer, Mr. J. H. Power, Dr. J. B. Robertson, and Col. J. G. Rose.

3. **Annual Report of Council for the year ended 30th June. 1945,** The Annual Report of the Council for the year ended 30th June, 1945. having been duly suspended on the Notice Board, was taken as read and adopted.

Jaarverslag van die Raad vir die jaar tot op 30 Junie 1945.—Die Jaarverslag van die Raad vir die jaar tot op 30 Junie 1945, wat behoorlik op die kennisgewingsbord gepubliseer was, is as gelees beskou en goedgekeur.

4. **Annual Report of the Honorary General Treasurer and Statement of Accounts for the year ended 31st May, 1945.**—The Honorary General Treasurer's Report and the Statement of Accounts for the year ended 31st May, 1945, having been duly displayed on the Notice Board, were taken as read and adopted.

Jaarsverslag van die Ere-algemene Penningsmeester en Staat van Rekeninge van die jaar tot op 31 Mei 1945.—Die verslag van die Ere-algemene Penningmeester en die Staat van Rekeninge vir die jaar tot op 31 Mei 1945, wat behoorlik op die Kennisgevingsbord gepubliseer is, is as gelees beskou en goedgekeur.

5. **Annual Report of the Honorary Librarian for the year ended 31st May, 1945.**—The Annual Report of the Honorary Librarian for the year ended 31st May, 1945, having been duly suspended on the Notice Board, was taken as read and adopted.

Jaarverslag van die Ere-bibliotekaris vir die jaar tot op 31 Mei 1945.—Die Jaarverslag van die Ere-bibliotekaris vir die jaar tot op 31 Mei 1945, wat behoorlik op die Kennisgewingsbord gepubliseer is, is as gelees beskou en goedgekeur.

6. **Election of General Officers and Members of Council for 1945/46.** The names of members elected as General Officers and Members of the Council for the year 1945/46 are given on page 2.

Verkiesing van Algemene Ampsdraers en Raadslede vir 1945/46. —Die name van die lede wat tot Algemene Ampsdraers en Raadslede vir die jaar 1945/46 gekies is, kom op bladsy 2.

7. Dr. F. E. T. Krause expressed his appreciation of the honour conferred on him in his election as President for the 1945/46 Session, and undertook to do all in his power to further the interests of the Association.

Dr. F. E. T. Krause het sy waardering uitgespreek vir die eer wat hom bewys is deur sy verkiesing tot President vir die jaar 1945/46, en het onderneem om alles in sy vermoë te doen om die belange van die Genootskap te bevorder.

8. It was agreed that it be left to the Cape Peninsula and District members of the Council to fill the vacancies for that Centre, and that it be left to the Council to fill the vacancy for East London and Port Elizabeth.

Dit is aangeneem dat aan die lede van die Kaapse Skiereiland en Distrik oorgelaat word om die vakatures vir daardie Sentrum te vul en dat die Raad vir die vul van die vakatures vir Oos-Londen en Port Elizabeth sal sorg.

9. **Subscriptions of Associate and Student Members.**—It was agreed to confirm the action of the Council in making the subscription for Associate Members for the 1944 Annual Meeting to be ten shillings, and for Student Members to be five shillings, instead of one pound and ten shillings and sixpence respectively, it being noted that this action had been taken as a result of the curtailment of the meeting to three days.

Ledegeld van Aspirant- en Studentlede.—Dit is ooreengekom om die handeling van die Raad, nl. die vasstel van ledegeld vir Aspirantlede vir die 1944-jaarvergadering op tien sjielings en vir Studentlede

op vyf sjielings, in plaas van een pond en tien sjielings en ses pennies respektiewelik, te bekragtig, terwyl aangeteken is dat hierdie besluit geneem is as gevolg van die verkorting van die Vergadering tot drie dae.

10. **Annual Meeting, 1946.**—As it was not known what venue would be suitable for the meeting because of transport difficulties, is was agreed that the Council have power to decide the date, duration and venue of the 1946 Annual Meeting.

Jaarvergadering, 1946.—Aangesien weens vervoermoeilikheid nie bekend was watter plek vir die hou van die vergadering geskik sou wees, is aangeneem dat die Raad mag sal hê om die datum, duur en plek van die 1946-jaarvergadering vas te stel.

11. **Resolutions from Section D.**

(a) Proposed by Dr. G. de Kock and seconded by Mr. A. O. D. Mogg:

"This meeting has noted the Memorandum of Council dealing with the protection and control of the Fauna, Flora and Sanctuaries, submitted by Council to the Government last year, and the reply received from the Minister of Lands that the time was not opportune to hold a meeting as recommended by Council.

"In view of the fact that hostilities have now ceased in Europe, this meeting recommends that Council again makes representations to the Government to convene a meeting of all interests concerned to consider how best to achieve the co-ordination of the work of all bodies controlling the National Parks, Game Reserves and Botanical Reserves."

(b) Proposed by Dr. A. J. T. Janse and seconded by Mr. A. O. D. Mogg:

"At the Congress Meeting of the South African Association for the Advancement of Science, of 4th July, 1945, our attention is directed to the recent destruction which has taken place in Europe, and which may have involved the destruction of a considerable amount of authentic zoological and botanical material. Concern is expressed about the chaotic effect this may have on zoological and botanical taxonomic work.

"This Congress therefore urges

(a) the necessity of investigating to what extent destruction has taken place, and what has been saved;

(b) that the results of this investigation be published;

(c) that steps be taken to fix nomenclature by international ruling according to the results of this investigation."

It was agreed to adopt the above resolutions and to refer them to the Council for action.

11. **Besluite van Afdeling D.**

(a) Voorgestel deur Dr. G. de Kock en deur Mnr. A. O. D. Mogg gesekondeer:

"Hierdie vergadering het kennis geneem van die Memorandum van die Raad met betrekking tot die beskerming en beheer van die Fauna, Flora en Sanctuaria, wat die Raad verlede jaar aan die Regering voorgelê het, en van die antwoord van die Minister van Lande dat die tyd nie gunstig is om 'n vergadering te hou soos deur die Raad aanbeveel is nie. Met die oog op die feit dat krygsbedrywe in Europa nou gestaak is beveel hierdie vergadering aan dat die Raad weer vertoë aan die Regering rig om 'n vergadering van alle betrokke belange byeen te roep om

te oorweeg hoe koördinasie van die werk van alle liggame wat die Nasionale Parke, Wildtuine en Botaniese Reserwes beheer, die beste bereik kan word."

(b) Voorgestel deur Dr. A. J. T. Janse en deur Mnr. A. O. D. Mogg geskondeer:

"Op die Kongresvergadering van die Suid-Afrikaanse Genootskap vir die Bevordering van Wetenskap, van 4 Julie 1945, is ons aandag gevestig op die onlangse vernietiging wat in Europa plaasgevind het en wat miskien vernietiging van 'n aansienlike hoeveelheid outentieke zoölogiese en botaniese materiaal ingesluit het. Met besorgdheid is gewag gemaak van die chaotiese gevolge wat dit vir zoölogiese en botaniese sistematiese werk kan hê.

"Hierdie Kongres beklemtoon daarom

(a) die noodsaaklikheid om te ondersoek in watter mate vernietiging plaasgevind het en wat gered is;

(b) die bekendmaking van die resultate van hierdie ondersoek;

(c) dat stappe gedoen word om nomenklatuur vas te stel by internasionale reëling ooreenkomstig die resultate van hierdie ondersoek."

Besluit is om die bostaande besluite aan te neem en na die Raad te verwys vir behandeling.

12. **Exhibition of Maps.**—On the proposal of Dr. J. I. Quin, seconded by Dr. R. A. Dyer, the following resolution was adopted and referred to the Council:

"(1) That this meeting records its sincere thanks to Dr. F. W. Fox for the exhibition of such a comprehensive series of South African maps of wide scientific interest.

"(2) That Council be urged to take the necessary steps for acquiring copies of all the maps exhibited, together with others that may in time become available, for safe keeping in the Library of the Association.

"(3) That these maps be fully catalogued with short descriptions of each, and listed in the Journal.

"(4) That some or all of these maps be exhibited at the annual meetings, depending on locality and general interest.

"(5) That members be urged to make use of these maps as far as possible and to collect copies of maps not yet in the possession of the Association."

Dr. Fox expressed his appreciation of the above resolutions, and stated that he was greatly indebted to Prof. J. H. Wellington, who had provided most of the maps exhibited.

Vertoning van Kaarte.—Op voorstel van Dr. J. I. Quin, deur Dr. R. A. Dyer gesekondeer, is die volgende besluite aangeneem en na die Raad verwys:

"(1) Dat hierdie vergadering sy hartlike dank aan Dr. F. W. Fox betuig vir die tentoonstel van so'n veelomvattende reeks Suid-Afrikaanse kaarte van groot wentenskaplike belang.

"(2) Dat die Raad dringend versoek word om die nodige stappe te neem vir die verkryging van al die tentoongestelde kaarte, saam met andere wat later verkrybaar word, vir veilige bewaring in die biblioteek van die Genootskap.

"(3) Dat hierdie kaarte, met 'n kort beskrywing van elkeen, volledig gekatalogiseer en in die Joernaal opgeneem word.

"(4) Dat sommige van hierdie kaarte, of almal, op die jaarvergadering vertoon word, afhanklik van plek en algemene belang.

"(5) Dat lede dringend versoek word om van hierdie kaarte soveel moontlik gebruik te maak en kopieë van kaarte wat nog nie in die besit van die Genootskap is nie, te versamel."

Dr. Fox spreek sy waardering van die bostaande besluit uit en verklaar dat hy groot dank verskuldig is aan Prof. J. H. Wellington, wat die meeste van die vertoonde kaarte verskaf het.

13. **Votes of Thanks.**—On the proposal of Dr. F. E. T. Krause a unanimous vote of thanks was accorded, firstly to the Mayor and City Council of Johannesburg for their courtesy and goodwill, as exemplified in the opening of the Annual Meeting by the Deputy Mayor (Councillor S. L. Lee) and the mayoral reception to be held that night; secondly, to The Associated Scientific and Technical Societies of South Africa for providing the necessary accommodation for the holding of the Annual Meeting in Kelvin House, and for granting the privilege of Honorary Membership to visiting members attending the meeting; thirdly, to the Honorary Auditors (Messrs. Alex Aiken & Carter) for their services in carrying out the audit for the year 1944/45; fourthly, to the Press for their services in reporting the proceedings of the Annual Meeting; and finally to the Witwatersrand Local Centre for the hospitality provided at the meeting.

Dr. H. E. Wood proposed a hearty vote of thanks to the President (Mr. E. C. Chubb) for the valuable services he had rendered the Association during his term of office, after which the President expressed his appreciation to Dr. G. de Kock (Vice-President) for conducting Council Meetings held during the year, which he had been unable to attend owing to his being resident in Durban.

Mosies van Dank.—Op voorstel van Dr. F. E. T. Krause is 'n eenparige mosie van dank aangeneem, in die eerste plek aan die Burgemeester en die Stadsraad van Johannesburg vir die hoflikheid en welwillendheid betoon deur die opening van die Jaarvergadering deur die Onder-Burgemeester (Raadslid S. P. Lee) en die Burgemeesterlike resepsie wat daardie aand gehou sal word; in die tweede plek aan die Verenigde Wetenskaplike en Werktuigkundige Verenigings van Suid-Afrika vir die verskaffing van die nodige geleentheid vir die hou van die Jaarvergadering in Kelvin-Huis en vir die goedgunstige toekenning van Ere-Lidmaatskap aan lede-besoekers wat die vergadering bywoon; ten derde aan die Ere-Ouditeure (die firma Alex. Aiken & Carter) vir hulle dienste in die uitvoering van die ouditering vir die jaar 1944/45; ten vierde aan die Pers vir die gepubliseerde verslae van die bedrywighede van die Jaarvergadering en ter slotte aan die Witwatersrandse Plaaslike Centrum vir die gasvryheid op die vergadering betoon.

Dr. H. E. Wood het 'n mosie van hartlike dank aan die President (Mnr. E. C. Chubb) voorgestel vir die waardevolle dienste wat hy die Genootskap gedurende sy ampstyd bewys het, waarna die President sy waardering aan Dr. G. de Kock (Vise-President) uitgespreek het vir die leiding van die Raadsvergaderings wat gedurende die jaar gehou is en wat hy weens sy verblyf in Durban nie kon bywoon nie.

REPORT OF COUNCIL FOR THE YEAR ENDING 30th JUNE, 1945
VERSLAG VAN DIE RAAD VIR DIE JAAR TOT OP 30 JUNIE 1945

Obituary/In Memoriam

1. **Obituary.**—Your Council reports with regret the deaths of the following members.

In Memoriam.—U Raad gee met leedwese kennis van die oorlyde van die volgende lede.

Mr. E. A. E. Collins, Mr. C. J. Edwards, Mr. J. H. Gilchrist, Mr. A. Hossack, Dr. W. E. Humphrey, Dr. C. F. Juritz, Mr. J. D. Low, Mr. D. W. Mackay, Dr. Hans Pirow, Mr. M. Pollak, Prof. A. Reid, Mr. A. R. Thompson and Dr. H. A. White.

Dr. Juritz, whose death is recorded above, joined the Association as a foundation member in 1903, he was Honorary General Secretary from 1910 until the time of his death, and was President for the year 1917/1918. Your Council wishes to place on record its great appreciation of the services rendered by Dr. Juritz in furthering the interests and advancement of the Association.

Dr. Juritz, wie se oorlyde hierbo vermeld is, het in 1903, by die Genootskap aangesluit as 'n Stigter-Lid. Hy was van 1910 tot die dag van sy dood Sekretaris, en President vir die jaar 1917/1918. U Raad wens sy groot waardering te boekstaaf van die dienste deur Dr. Juritz bewys by die bevordering van die belange en die vooruitgang van die Genootskap.

2. **Membership.**—Since the last report fifty-four members have joined the Association, thirteen have died and five have resigned.

The following table shows a comparative list of the geographical distribution of membership as at the 30th June, 1944, and the 30th June, 1945.

Ledetal.—Sedert die jongste verslag het vier-en-vyftig lede by die genootskap aangesluit, dertien is oorlyde en vyf het bedank. Die volgende lys toon, vergelykenderwys, die geografiese voorkoms van lede op 30 Junie 1944 en 30 Junie 1945.

	1944	1945
Transvaal	364	396
Cape of Good Hope	158	156
Natal	72	70
Orange Free State	21	21
Southern and Northern Rhodesia	11	12
South-West Africa	2	1
Moçambique	2	2
Abroad	20	28
	650	686

3. **The Journal.**—Volume XLI of the "South African Journal of Science," being the Annual Report of the Association for the year ending 30th June, 1944, was circulated to members in June, 1945.

It consisted of 585 pages and contained the Address of the President of the Association, five Sectional Presidential Addresses, and fifty-eight other papers, of which forty-eight were printed in full, eight in abstract and two in title only, together with Indexes, Accounts, etc.

Die "Journal."—Deel XLI van die Suid-Afrikaanse Journal van Wetenskap, wat die jaarverslag van die Genootskap vir jaar tot op 30 Junie 1944 bevat, is in Junie 1945 aan die lede voorgelê. Dit het uit 585 bladsye bestaan en het die rede van die President van die Genootskap, vyf Voorsitterstoesprake aan afdelings en agt-en-vyftig lesings waarvan agt-en-veertig volledig, agt in abstracto en twee slegs die tietel, benewens inhoudsopgawe, rekenings, ens., bevat.

4. **Quarterly Bulletins.**—Three bulletins were issued during the year under review, in July, 1944, and in April and June, 1945, respectively.

Kwartaal-Bulletins.—Gedurende die jaar is drie bulletins uitgegee, respektiewelik in Julie 1944 en April and Junie 1945.

5. **South Africa Medal and Grant, 1945.**—Your Council has awarded the South African Medal, together with a grant of £40 15s. 11d. to Dr. Keppel H. Barnard. The recommendation was made by the Medal Committee, consisting of the following.

Suid-Afrika-Medalje en Skenking, 1945.—U Raad het die Suid-Afrika-medalje saam met 'n skenking van £40 15s. 11d. toegeken aan Dr. Keppel H. Barnard. Die aanbeveling is gedoen deur die Medalje-komitee, bestande uit die volgende lede.

Dr. G. de Kock (Chairman), Prof. A. W. Bayer, Lt.-Col. C. Graham Botha, Dr. S. F. Bush, Dr. A. L. du Toit, Dr. T. D. Hall, Prof. P. R. Kirby, Prof. I. D. MacCrone, Prof. L. F. Maingard, Dr. A. Pijper, Dr. E. C. N. van Hoepen and Dr. H. E. Wood.

The Secretary of the British Association has been notified of the award.

Die Sekretaris van die Britse Genootskap is van die toekenning in kennis gestel.

6. **British Association Medal, 1945.**—No award. Geen toekenning.

7. **Donations.**—The thanks of the Association are due to the Honourable the Minister of Finance and of Education for a grant of £250 towards the expenses of the publication of the Journal, and to the Johannesburg Municipality for a grant of £100.

Gifte.—Die Genootskap spreek sy dank uit aan Sy Ed. die Minister van Finansies en Onderwys vir 'n gif van £250 tot die onkoste van die uitgawe van die Journal, en aan die Johannesburgse Munisipaliteit vir 'n toelae van £100.

8. **Resolutions Adopted by Annual General Meeting, 4th July, 1944.**

(a) Establishment of State Film Institute.—A copy of this resolution was sent to the Prime Minister. A letter supporting the resolution has been sent by the Controlling Executive of the Associated Scientific and Technical Societies.

(b) Preservation of Elephants and Cape Buffalo in the Addo Reserve.—A letter embodying this resolution was sent to the Minister of Lands.

Besluite aangeneem deur die algemene jaarvergadering, 4 Julie 1944.

(a) Oprigting van Staats-Rolprentinstituut.—Hierdie besluit is aan Sy Edele die Eerste Minister gestuur. 'n Brief tot ondersteuning van die besluit is deur die Beherende Uitvoerende Raad van die Verenigde Wentenskaplike en Werktuigkundige Verenigings gestuur.

(b) Behoud van Olifante en Kaapse Buffels in die Addo-Wildtuin. 'n Brief wat hierdie besluit bevat is aan Sy Ed. die Minister van Lande gestuur.

9. **Resolution Adopted by Annual General Meeting, 29th June, 1943.**

Protection and Control of the Fauna, Flora and Sanctuaries in South Africa. (See Council's Report, 1944, item 9 (a).)

A letter has been received from the Secretary for Lands in which he advised that the Minister was of the opinion that under prevailing conditions no good purpose could be served by holding a joint conference to consider the co-ordination of all Reserves in South Africa.

Copies of the Council's Report on National Parks have now been sent to all organisations interested in the subject. These organisations have been requested to use their influence to persuade the Minister of Lands to convene a meeting of all interests concerned, with a view to considering whether or not some form of co-ordination of the bodies controlling the National Parks, Game Reserves and Botanical Reserves of the Union be desirable, and the advisability of scientific representation on such bodies.

Besluite aangeneem deur die Algemene Jaarvergadering, 29 Junie 1943.

Beskerming en beheer van die fauna, flora en sanctuaria in Suid-Afrika. (Verslag van die Raad, 1944, item 9 (a).)

Van die Sekretaris van Lande is 'n brief ontvang waarin hy meedeel dat die Minister van mening is dat dit onder die huidige omstandighede van geen nut sou wees om 'n gesamentlike konferensie vir die oorweging van die koördinasie van alle Reserwes in Suid-Afrika te hou nie.

Afskrifte van die Raad se Verslag oor Nasionale Parke is nou aan alle organisasies wat in die daarby betrokke vraagstukke belang stel, gestuur. Hierdie organisasies is versoek om hulle invloed aan te wend en die Minister van Lande te beweeg om 'n vergadering van alle betrokke belange byeen te roep vir oorweging van die raadsaamheid van een of ander vorm van koördinasie van die liggame wat die Nasionale Parke, Wildtuine en Botaniese Reserwes van die Unie beheer.

10. **Policy of the Association in its Relations with the Public.**—The Council has appointed a Public Relations Committee to make definite proposals for informing the public and stimulating their interest in scientific matters. This Committee will function in the Witwatersrand and Pretoria area. The Durban centre is forming a similar committee.

Beleid van die Genootskap in sy Verhouding tot die Publiek.—Die Raad het 'n Publieke Verhoudingskomitee aangestel om bepaalde voorstelle te doen omtrent die gee van informasie aan die publiek en die opwekking van sy belangstelling in wetenskaplike sake. Hierdie Komitee sal in die Witwatersrand- en die Pretoriadistrik werk. Die Durban-Sentrum vorm 'n dergelike Komitee.

11. **Public Service Enquiry Commission.**—Your Council submitted a memorandum to this Commission.

Staatsdiens Kommissie van Ondersoek.—U Raad het 'n memorandum aan hierdie Kommissie voorgelê.

12. **Annual Meeting, 1945.**—Your Council again arranged a short session of three days, 2nd, 3rd and 4th July, in Johannesburg. This year more time has been made available for Section Meetings.

Jaarvergadering, 1945.—U Raad het weer 'n kort sitting van drie dae, 2, 3 en 4 Julie, in Johannesburg gereël. Hierdie jaar is meer tyd vir Afdelingsvergaderings beskikbaar gestel.

13. **The New Council.**—On the basis of membership provided in the Constitution, Section 22, the number of members of Council assigned to each centre during the ensuing year should be as follows:

Die Nuwe Raad.—Die aantal Raadslede vir elke sentrum gedurende die volgende jaar, moet, soos in die Statute, Artikel 22, bepaal, op die basis van die ledetal as volg verdeel word.

Transvaal.	
Witwatersrand	18
Pretoria	6
Outside Districts/Buitedistrikte	1
Province of the Cape of Good Hope.	
Cape Peninsula and District/en Distrik	6
Stellenbosch and District/en Distrik	2
East London and Port Elizabeth	1
Grahamstown, Kingwilliamstown and District/en Distrik	1
Kimberley	1
Oudtshoorn	1
Outside Districts/Buitedistrikte	1
Natal.	
Durban and District/en Distrik	3
Pietermaritzburg and Outside Districts/en Buitedistrikte	2
Orange Free State.	
Bloemfontein and District/en Distrik	1
Southern Rhodesia	1
	45

14. **Honorary Auditors.**—The thanks of the Association are again due to Messrs. Alex. Aiken & Carter, the Honorary Auditors, who have audited the Accounts of the Association for 1944-45.

Ere-ouditeure.—Die Genootskap is weer dank verskuldig aan die firma Alex. Aiken & Carter, die Ere-ouditeure, wat die Rekeninge van die Genootskap vir 1944-45 geouditeer het.

15. **Secretariat.**—The Council tenders its thanks to the Associated Scientific and Technical Societies for their services as Assistant General Secretaries of the Association throughout the year, and expresses its appreciation of the unfailing help given by Mr. A. J. Adams and Mr. I. M. Sinclair.

Sekretariaat.—Die Raad bring sy dank aan die Verenigde Wetenskaplike en Werktuigkundige Verenigings vir hulle dienste as Assistent-Algemene Sekretarisse van die Genootskap gedurende die jaar, en spreek sy waardering uit vir die getroue hulp wat Mnr. A. J. Adams en Mnr. I. M. Sinclair verleen het.

Report of the Honorary General Treasurer for the year ended 31st May, 1945

The continued rise in the cost of printing the Journal, which has been commented on in past years, has to be referred to again. Thus the gross cost of printing the Journal is £500 greater than last year, while the net cost was £422 more. The deficit last year was £33, and this year it is £357. In consequence the balance of our Income and Expenditure Account has been reduced to £142.

These results justify careful consideration being given by the Editorial Committee to contributions which are submitted for publication, so as to ensure that those accepted are of high merit.

The income from subscriptions has increased by £77 in a total of £733; an encouraging feature, but indicating a membership which is by no means representative of those persons who are professionally engaged in the practice of one or other of the sciences in South Africa, or of the large number of those who are interested in the advancement of science.

It should be our endeavour to increase the membership to a figure commensurate with the importance of the Association and thus add substantially to our income.

We are very grateful to the Union Department of Education and the City Council of Johannesburg for continued assistance by means of grants towards the cost of printing the Journal.

It is obvious that without the generous donors we would be unable to carry out one of our main functions.

JAS. GRAY,
Honorary General Treasurer.

Verslag van die Ere-Algemene Penningmeester vir die jaar tot op 31 Mei 1945

Dit is nodig om die aanhoudende verhoging in die drukkoste van die "Journal," wat die laaste jare onder u aandag gebring is, weer te bespreek. Die brutokoste van die druk van die "Journal" is £500 meer as verlede jaar en die nettokoste £422 meer. Die verlies was verlede jaar £33 en hierdie jaar £357. Bygevolg is ons Inkomste en Uitgawe-Rekening tot £442 verminder.

Hierdie syfers maak dit nodig dat die Redaksionele Komitee die artikels wat vir publikasie aangebied word, streng beoordeel sodat die wat aangeneem word van 'n hoë gehalte is.

Die inkomste van subskripsies is met £77 vermeerder tot 'n totaal van £733; dit is bemoedigend, maar toon 'n lede-aantal wat in geen geval verteenwoordigend is van die persone wat professioneël in die beoefening van een of ander wetenskap in Suid-Afrika werksaam is, of van die groot aantal van die wat in die bevordering van Wetenskap belangstel.

Ons moet probeer om die ledetal op te bring tot ' n syfer wat in verhouding is tot die belangrikheid van die Genootskap, en sodoende tot die inkomste belangrik bydra.

Ons is baie dankbaar aan die Regerings-Department van Onderwys en die Stadsraad van Johannesburg vir die voortsetting van hulle bydrae, by wyse van skenkings, tot die drukkoste van die "Journal."

Dit is duidelik dat ons sonder die edelmoedige gewers nie instaat sou wees om een van ons vernaamste funksies ten uitvoer te bring nie.

JAS. GRAY,
Ere-Algemene Penningmeester.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

BALANCE SHEET AT 31st MAY, 1945.

LIABILITIES.

Sundry Creditors:		
General Accounts	£1,254 17 4	
Grants to Local Centres under Rule 35	45 19 0	
Recipient South Africa Medal Award, 1945	40 15 11	
Subscriptions paid in advance	25 1 0	
Endowment Fund	34 3 3	
		£1,400 16 6
Library Binding and Equipment Account:		
Balance at 31st May, 1944	217 13 7	
Add—Interest from Library Endowment Fund	73 18 0	
	291 11 7	
Less—Expenditure during year	33 5 8	
		258 5 11
Income and Expenditure Account:		
Balance at 31st May, 1944	799 15 10	
Less—Excess of Expenditure over Income for the year ended 31st May, 1945	357 4 6	
		442 11 4
		2,101 13 9
Endowment Fund		3,332 14 5
Library Endowment Fund		2,164 11 6
South Africa Medal Fund		1,670 9 1
British Association Medal Fund		517 2 6
		£9,786 11 3

ASSETS.

Cash:		
At Bank	£987 10 10	
At Post Office Savings Bank, with Interest accrued	40 17 2	
At United Building Society, St. Andrew's Branch, with Interest accrued	968 6 9	
		£1,996 14 9
Sundry Debtors:		
Library Endowment Fund	3 18 0	
Advertisers in Journal	77 15 0	
		81 13 0
Furniture:		
Balance at 31st May, 1944	27 3 6	
Less—Depreciation	5 13 6	
		21 10 0
Medals on Hand		1 16 0
		2,101 13 9
Trustees—Endowment Fund, as per separate Account		3,332 14 5
Library Endowment Fund, as per separate Account ...		2,164 11 6
Trustees—South Africa Medal Fund, as per separate Account		1,670 9 1
Trustees—British Association Medal Fund, as per separate Account		517 2 6
		£9,786 11 3

We have examined the books, accounts and vouchers of The South African Association for the Advancement of Science for the year ended 31st May, 1945, and have obtained all the information and explanations we have required. We have satisfied ourselves of the existence of the securities. Proper books and accounts have been kept. In our opinion the above Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of affairs of the Association at 31st May, 1945, according to the best of our information and the explanations given to us and as shown by the books of the Association as at 31st May, 1945.

Johannesburg,
14th June, 1945.

ALEX. AITKEN & CARTER,
Auditors.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1945.

Dr.

To Secretarial Fees			£240 0 0
„ Journal Expenses		£1,353 3 5	
Less—Government Grant	£250 0 0		
Johannesburg Municipal Grant	100 0 0		
Sales, Reprints and Advertisements ...	212 1 0		
		562 1 0	
			791 2 5
„ Stationery and Printing			29 4 0
„ Postages			27 14 8
„ Expenses—Annual Meeting, 1944			7 0 0
„ Sundry General Expenses			13 12 10
„ Grants to Local Centres under Rule 35:			
Witwatersrand	£31 5 0		
Cape of Good Hope ...	10 1 0		
Natal	4 13 0		
		45 19 0	
Less—Grant outstanding for Natal Centre for year ended 31st May, 1944, not claimed		6 5 6	
			39 13 6
„ Depreciation on Office Furniture ...			5 13 6
„ Pension—H. A. G. Jeffreys			90 0 0
			£1,244 0 11

Cr.

By Annual Subscriptions	£651 18 0	
„ Arrear Subscriptions	76 0 0	
„ Associates' Fees	3 10 0	
„ Students' Fees	2 0 0	
		£733 8 0
„ Interest:		
From Endowment Fund	131 9 3	
United Building Society, St. Andrew's Branch, Savings Account	17 19 7	
Post Office Savings Bank Account ...	0 19 7	
		153 8 5
„ Balance, being Excess of Expenditure over Income, for the year ended 31st May, 1945, transferred against Accumulated Funds		357 4 6
		£1,244 0 11

We report that, to the best of our knowledge and belief and on the information supplied to us, the above account reflects a true statement of the income and expenditure of the Association for the year ended 31st May, 1945.

Johannesburg,
14th June, 1945.

ALEX. AIKEN & CARTER,
Auditors.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

ENDOWMENT FUND.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1945.

Dr.		Cr.	
To Interest, as per contra, transferred to General Fund	£134 9 3	By Interest received during the year	£134 9 3
,, Balance, transferred to Accumulated Funds	58 0 0	,, Life Membership Subscriptions	58 0 0
	£192 9 3		£192 9 3

BALANCE SHEET AT 31st MAY, 1945.

LIABILITIES.			ASSETS.		
Accumulated Funds:			Investments in hands of Trustees—		
Balance at 31st May, 1944 ...	£3,271 11 5		Cape Town Municipality $3\frac{3}{4}$% Stock	£1,150 0 0	
Add—Amount transferred from Income and Expenditure Account	58 0 0	£3,332 14 5	Cape Town Municipality 4% Stock	300 0 0	
			Cape Town Municipality 5% Stock	240 0 0	
			Cape Town Municipality 5% Stock	800 0 0	
			Port Elizabeth Municipality $3\frac{1}{2}$% Stock	100 0 0	
			Cape of Good Hope Savings Bank	708 11 2	£3,298 11 2
			Amount due from General Fund		34 3 3
		£3,332 14 5			£3,332 14 5

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

LIBRARY ENDOWMENT FUND.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1915.

Dr.		Cr.	
To Balance, transferred to Library Binding and Equipment Account	£73 18 0	By Interest received during the year	£73 18 0
	£73 18 0		£73 18 0

BALANCE SHEET AT 31st MAY, 1915.

LIABILITIES.		ASSETS.	
Amount due to General Fund	£3 18 0	Investments:	
Accumulated Funds: Balance at 31st May, 1944	2.164 11 6	£2,000 City of Johannesburg 3½ per cent. Local Registered Stock, 1965—at Cost ...	£1,970 0 0
		Cash at United Building Society, St. Andrew's Branch—Savings Bank Account	198 9 6
	£2,168 9 6		£2,168 9 6

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SOUTH AFRICA MEDAL FUND.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1945.

Dr.		Cr.	
To Expenses in connection with 1945 Award ..	£9 5 4	By Interest received during the year	£50 1 3
,, Amount of 1945 Award	40 15 11		
	£50 1 3		£50 1 3

BALANCE SHEET AT 31st MAY, 1945.

LIABILITIES.		ASSETS.	
Accumulated Funds:		Investment in Hands of Trustees:	
Balance at 31st May, 1944	£1,670 9 1	Fixed Deposit, South African Permanent Mutual Building and Investment Society ...	£1,670 9 1
	£1,670 9 1		£1,670 9 1

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE BRITISH ASSOCIATION MEDAL FUND.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1945.

Dr.		Cr.	
To Balance transferred to Accumulated Funds	£18 5 3	By Interest received during the year ...	£18 5 3
	£18 5 3		£18 5 3

BALANCE SHEET AT 31st MAY, 1945.

Liabilities.			Assets.	
Accumulated Funds:			Investments in Hands of Trustees:	
Balance at 31st May, 1944 ...	£498 17 3		£450 Union of South Africa 3¾ per cent. Local Registered Stock, 1948/58	£450 0 0
Add—Amount transferred from Income and Expenditure Account	18 5 3		Post Office Savings Bank	67 2 6
		£517 2 6		
		£517 2 6		£517 2 6

Report of the Honorary Librarian for the year ended 31st May, 1945.

Verslag van die Ere-Bibliotekaris vir die jaar geëndig 31 Mei 1945

The Association's Library is housed in the Library of the University of the Witwatersrand, Johannesburg. The collection includes about 3,800 volumes, and 180 different titles are received currently.

Die Genootskap se Biblioteek word in die Biblioteek van die Universiteit van die Witwatersrand, Johannesburg, gehuisves. Die versameling bevat omtrent 3,800 bande, en 180 verskillende titels word lopend ontvang.

South African Journal of Science.—Since the last report exchange relations have been established with the following:

Suid-Afrikaanse "Journal" van Wetenskap.—Sedert die laaste verslag is omruilings-verhoudinge met die volgende gestig:

Arquivos de Angola.
Canada Department of Agriculture.
Ceylon University.
Indian Science Congress Association.
National Research Council, Canada.
Tanganyika Department of Agriculture.
Zoological Society of London.

At the request of the Royal Danish Consul-General, in Johannesburg, volumes of the Journal, which had not been received during the war years, were sent to him for transmission to the K. Danske Videnskabernes Selskab in Copenhagen.

Volumes of the Journal are also being sent currently to Biological abstracts in which articles from the Journal are now summarised.

Op versoek van die K. Deense Konsul in Johannesburg is dele van die Journal, wat nie gedurende die oorlogsjare ontvang is nie, na hom vir oorsending na die K. Danske Videnskabernes Selskab in Kopenhagen gestuur.

Dele van die "Journal" word ook lopend aan Biological abstracts gestuur waarin artikels van die "Journal" now opgesom word.

Donations from the following are gratefully acknowledged:

Geskenke van die volgende word dankbaar erken:

Director, Agriculture Research Institute, Pretoria: South African Journal of Science, 1924-31.

British Museum (Natural History): Exell, A. W., Catalogue of the Vascular Plants of S. Tome.

Mr. E. M. Evans: South African Journal of Science (seven numbers).

Judge F. E. T. Krause: Penal Reform and its Social Implications.

Rural Economics Survey, Johannesburg. Boyazoglu, A., Nature and Extent of the Unity of Agricultural Education.

Mrs. J. F. Solly: South African Journal of Science (four volumes and twenty parts).

Soviet Scientists' Anti-Fascist Committee: Report of the Third Meeting, Moscow, 1944.

Miss H. M. White: South African Journal of Science (volumes 37 and 38).

Accessions to Serial Publications, 1944/45

Aanwinste tot Periodieke Publikasies, 1944/45

Arquivos de Angola, Luanda. 1, 1943+.

Association des Ingenieurs, Elisabethville Bulletin. 5, 1943+.

Portugal. Ministerio das Colonias. Memorias. Serie antropologica e etnologica. 1, 1944+.

Reading, Pa. Public Museum and Art Gallery. Bulletin. 5, 1924+. Scientific Publications. 1, 1941+.

Science in the U.S.S.R. 2, 1943+.

Scientific Agriculture. Ottawa. 23, 1942+.

Zoological Society of London: Proceedings. Series A. 109, 1939+ Series B. 109. 1939+.

For a Catalogue of Serial Publications in this Library, and Supplement, see this Journal, vol. 30, pp. xxv-xxix, and vol. 34, pp. xxxiv-xxxvii. Subsequent accessions are listed in the Annual Report.

Vir 'n Katalogus van Periodieke Publikasies in die Biblioteek, en Supplement, sien hierdie "Journal" band 30, b xxv-xxix, en band 34, b. xxxiv-xxxvii. 'n Lys van latere aanwinste word in die Jaarlikse Verslag gegee.

P. PREER,

Hon. Librarian/Ere-Bibliotekaris.

University of the Watwatersrand/Universiteit van die Witwatersrand, Johannesburg.

9th June/9 Junie 1945.

In Memoriam.

HANS PIROW, D.Sc.

Dr. Pirow was born at Aberdeen in the Central Karroo on March 10th, 1892, and was educated at Potchefstroom and in Germany. He returned to South Africa in 1911 to study mining engineering at the S.A. School of Mines and qualified in 1914. After working in different capacities on several mines until 1919, he obtained the M.Sc. degree, a Government Research Scholarship, and an appointment as Inspector of Mines. In 1923 he obtained his D.Sc. from the Witwatersrand University, his thesis dealing with the "Underground conditions liable to affect the health of mine workers."

In 1924 he obtained the Dominion Science Scholarship and left to continue his mainly technical and hygienic researches in England and on the continent. On his return in 1925 he became assistant consulting engineer to the Union Corporation, and in December, 1926, he succeeded Sir Robert Kotze as Government Mining Engineer.

Ten years later he left the public service for a managership of the Central Mining and Investment Corporation, became a director of the Rand Mines, Ltd., and chairman of many great mines of that group, including the Blyvooruitzicht mine which made such remarkable progress under his administration.

Dr. Pirow was a member of many important government bodies, including the Industrial and Agricultural Development Commission, and the Economic and Social Planning Council, on all of which he brought to bear his administrative knowledge, discernment and initiative. He joined this Association in 1926 and was also a member of many other scientific and technical societies in Johannesburg, to whose discussions and work he contributed materially.

Dr. Pirow passed away on January 7th, 1945, and the loss of his great abilities, of his practical sympathy with the underground workers, of his discernment and of his devotion to fundamental national and social interests will be deeply regretted by all who were associated with his life's work.

CHARLES FREDERICK JURITZ, M.A., D.Sc., F.I.C., F.R.S.E.

In Memoriam.

Dr. Juritz, who died at Sea Point on the 15th May, 1945, spent most of his 81 years at the interesting "Villa Marina," Three Anchor Bay, where he was born on the 3rd March, 1864.

He had a brilliant career at the South African College, where he won the Queen Victoria Scholarship, among others, and took his M.A. degree in 1886. Appointed at Senior Analyst to the newly-created Government Chemical Laboratory in Cape Town, he administered that department with ability, initiating and directing its ever-widening activities for many years, and was indeed responsible for various important statistics dealing with Foods, Drugs, Wines, Fertilisers, etc. The writer recalls many visits to that unpretentious building in Parliament Street, since swept away.

In 1893 he began the soil work that led to the first Soil Survey in S.A. Upon it was written his thesis on the Agricultural Soils of the Cape Colony—printed in 1909—for which he was awarded the D.Sc. degree in 1907. In this, as was customary at the time, the chemical aspect of soil formation was somewhat overstressed. After Union he became head of the new Division of Chemistry, with branches in several centres, as position which he retained until his retirement in 1924.

In 1914, at the invitation of the Commonwealth Government, he visited Australia with the British Association, and studied some of its agricultural problems. He was the author of many valuable departmental reports as well as pamphlets dealing with a variety of subjects, from the chemical composition of underground waters and of rain to that of native poisons.

Apart from his numerous scientific contributions, of which fourteen appeared in this Journal between 1909 and 1919, Dr. Juritz will ever be remembered for his efforts towards the organisation of this Association, of which he was a Foundation Member. Except for the year 1917-18, when he was President of the Association, he was Joint Honorary Secretary from 1910 to the date of his death, and Honorary Editor of this Journal for the ten years 1909-1918; throughout that long period the Association has owed much to his initiative, guidance and energy. At the annual meetings, save during the past two years, when his state of health prevented him from playing so active a part, he was always to the fore, and his friendly and genial nature and manner made him always a welcome and desired personality.

To the Juritz family too were due the artistic embroidered Presidential Banners and the Shields that up to recent years graced the walls at the yearly assemblies.

After 1924, and to the loss of Chemistry, he entered public life and served on the Cape Town City Council from 1926-32, and on the Divisional Council from 1925-39. The Dutch Reformed Church at Three Anchor Bay claimed him as organist for no less than 60 years.

Dr. Juritz was a Fellow of the Royal Society of S.A., a Fellow of the Royal Institute of Chemistry of Great Britain and Ireland, and, apart from his professional doctorate, a D.Sc. *honoris causa*, of the University of Adelaide. With his passing, the Association has lost one of its distinguished builders, and Chemistry a notable figure.

A. L. d. T.

In Memoriam.

DR. P. W. LAIDLER, L.R.C.S. & P., L.D.S., D.P.H., F.S.A.

Dr. Laidler, the Head of the Public Health department of East London, came to South Africa in 1910, joined this Association in 1928, was elected as a member of the Council of the Association from 1938 to 1945, and died at Stellenbosch on the 31st August last year.

Dr. Laidler gained a wide reputation as an archaeologist, his work being recorded in a long series of contributions to the scientific press, ten of which appeared during the years 1928 to 1937 in the annual reports of the Association (this JOURNAL). In 1938 he published in book form his collected papers on the "Characteristics and Classification of South African Native Ceramics."

Dr. Laidler was greatly interested in many aspects of South Africa's past, and his book on the "Bibliography of Pre-Victorian Products in the Cape Press," on the "Annals of the Cape Stage" and on Cape Town, "The Tavern of the Ocean," testify to the extent and variety of his interests. His researches in his professional subjects are represented by a number of pamphlets and papers on medicine and public health, among which may be mentioned his "Medico-social aspects of population density," his "Organisation of a health programme in Durban areas," and his "Practice of Eugenics."

In East London, he took a great part in all civic and social affairs, being a member or officer of many public bodies, in all which his willing and ready help and his sound judgment were highly esteemed and his untimely demise deeply deplored.

South African Journal of Science, *Vol. XLII, pp. 1-17, June, 1946.*

MUSEUMS AND THE ADVANCEMENT OF SCIENCE

BY

E. C. Chubb,

Director of the Durban Museum.

Presidential Address to the South African Association for the Advancement of Science, July, 1945.

I have chosen to address you on the subject of Museums and the Advancement of Science because in the first place my life's work has been connected with museums, first at the British Museum (Natural History), then at the Rhodesia Museum, Bulawayo (now the National Museum of Southern Rhodesia) and for the last thirty-five years at the Durban Museum; and in the second place on account of the similarity of the aims of museums and those of our Association, namely, the advancement and the diffusion of science. The objects of our Association, as defined in the first paragraph of its Constitution, are:—To promote the intercourse of societies and individuals interested in science in different parts of South Africa; to obtain a more general attention to the objects of pure and applied science and the removal of any disadvantages of a public kind which may impede its progress; and to give a stronger impulse and a more systematic direction to scientific enquiry and research.

The functions of museums have been variously defined, but most authorities regard research and education as primary functions, especially of museums devoted to science. One authority adds inspiration as a third function of museums. Bound up with these is the function of conservation—the collection and preservation of objects of scientific, historical, or artistic importance, for the benefit of present and future generations. Markham, one of the leading authorities in Britain to-day, definies three great functions, namely, (1) to collect and conserve objects of cultural importance; (2) to assist research workers, students, etc., in every possible way and (3) to educate and inspire.

The extent to which these separate functions are carried out varies in accordance with such factors as (a), the authority to which the museum belongs or from which it derives its chief financial support, (b) the nature and scope of the museum, (c) the aims and objects for which it was established, and (d) the class of visitors to whom it is to appeal, or the class of person which forms the bulk of its visitors—whether investigators, students, or the public generally.

Research and education, or the increase and diffusion of knowledge, are the common aims of museums and of our Association, though they are attained by different means.

The first recorded institution that bore the name of museum was that seat of learning at Alexandria founded by Ptolemy Soter about the year 300 B.C. and destroyed in the year 48 B.C., when Julius Caesar besieged the City. This was not a museum in the accepted modern sense but a place used for the cultivation of learning, where philosophers met for the improvement of their knowledge by lectures and discussions.

The earliest museum entitled to the name in its modern use was, however, a small private one, formed about 2,500 years ago and discovered by Sir Leonard Woolley during excavations in Mesopotamia on behalf of the British Museum and the University Museum, Philadelphia. In his book "Ur of the Chaldees," Woolley says that he was astonished at coming upon a room in which there was a collection of objects of historical importance, among which was a drum-shaped clay object bearing four columns of writing. This room, he states, was a museum of local antiquities maintained by the Princess Bel-Shalti-Nannar (who in this respect took after her father, a keen archaeologist), and the clay drum was the earliest museum label known, drawn up a hundred years before and kept as a record of the first scientific excavation at Ur!

Collections of curiosities, rarities and other objects have been formed throughout the ages. The Romans made collections of statues, paintings, precious stones and curiosities of nature, and these were often preserved in their temples. In the middle ages it was customary for princes and dignitaries of the church to possess and to carry about with them in a chest or reliquary, collections of the relics of saints; and most churches had their treasuries, in which were collections of relics, and often curiosities and rarities brought back by pilgrims and travellers from other countries. Although the formation of such collections was prompted by piety and superstition rather than for the purpose of study and instruction, it no doubt encouraged the collecting habit and resulted in the preservation of interesting objects, some of which in later times found their way into museums.

With the revival of learning in the fifteenth century there followed a keen appreciation of the monuments of classical antiquity and an eager desire to possess them. Excavations on ancient sites were carried on extensively; and between the years 1450 and 1550 an immense number of antiquities were obtained by this means in Rome and its environs, some of which were acquired for collections that eventually formed the foundations of the museums of the Vatican and the Lateran at Rome, and for the principal museums of Florence, Vienna, Paris and London. Coins and medals also came to be sought after, and by the middle of the sixteenth century it is said there were some 200 collections in France, 380 in Italy, 175 in Germany and 200 in the Low Countries. Other objects to which collectors devoted their attention were engraved gemstones. The first English

collector of these was Thomas Howard, Earl of Arundel, who lived from 1586 to 1646.

With the discovery of the sea route to India by Vasco da Gama in 1497 and the discovery of America in 1492, resulting in the establishment of trading centres in the East and West Indies and the undertaking of missionary enterprises, Europeans were brought into touch with distant lands and a regular traffic in rarities and curiosities from overseas soon followed. About the same time interest began to be taken in objects of animate nature, and this led to the naturalists of the sixteenth and seventeenth centuries becoming as eager in their search for plants and animals as were the collectors of objects of antiquity in the preceding centuries. Amongst these early collectors of natural history specimens was Conrad Gesner of Zurich, who lived during the first half of the sixteenth century and to whom archaeologists are indebted for the first illustrated account of stone implements, and Anselm de Boodt of Bruges, a collector of rocks and minerals and the author of a book on gems and stones, published in 1609 and for long a standard work on the subject.

During the sixteenth century the term "Museum" came to be applied to these early private collections, and from the end of the century it was constantly used not only for the collections but also for the buildings in which they were kept.

There were many notable private museums in the leading cities of Europe during the sixteenth and seventeenth centuries. For instance, Gaston, Duke or Orleans, son of Henry IV of France, had an extensive collection of natural history specimens which was purchased by Colbert in 1660 and, after being enriched by numerous additions, became in 1793 the foundation of the Museum of Natural History at Paris.

John Tradescant, who died in 1638, and his son were two of the earliest English naturalists and collectors. At one time their private museum was considered to be the most extensive in Europe. It was acquired by Elias Ashmole in 1659, incorporated with his own collection, and twenty-three years later the whole given to the University of Oxford where it formed the celebrated Ashmolean Museum.

The Royal Society of London, shortly after its incorporation in 1660, began to form a museum, which became one of the attractions of London and ultimately went to the British Museum.

Sir Hans Sloane, a celebrated London physician of the latter part of the seventeenth and first half of the eighteenth centuries, and president of the Royal Society for thirteen years, built up one of the greatest private museums, partly from his own collecting and partly from the purchase of many important collections made by others. By 1725 the specimens in his museum numbered 53,018, by 1733 they increased to 69,352 and went on increasing for the next twenty years. On his death the museum and library, which together had cost £50,000 and were

valued at £80,000, we bequeathed to the nation on condition that an amount of £20,000 was paid to his executors and that the public would be admitted free to the museum. The bequest was accepted; and an act of parliament was passed which authorised the raising of the necessary funds by state lottery for the purpose, and also for purchasing the Harley collection of manuscripts then in the market, as well as for acquiring a building in which to accommodate them. The lottery was duly formed, 50,000 tickets being printed and the prizes offered varying from £10 to £10,000. It resulted in a sum of £95,000 being obtained, of which £23,000 was used for the purchase of Montagu House (on the site of the present British Museum) and for structural alterations and equipment.

In 1759, after the collections had been properly installed, the public were admitted free daily, in accordance with the terms of Sloane's will; but not freely, for admission could only be obtained by ticket, and the intending visitor had to apply at the porter's lodge a few days previously and enter in a register his name, occupation and address. This was submitted to the Director who, if he approved, issued a ticket which had to be called for and was not transferable. Moreover, visitors were admitted in parties and rapidly conducted through the various rooms, only one hour being allotted to each party for the inspection of the whole museum; and for a number of years not more than sixty persons were admitted on any one day. These restrictions appear absurdly onerous to us at the present time, but it must be remembered that there was a notoriously unruly section of London's populace at that period and no efficient police service; and the museum authorities, while giving effect grudgingly to Sloane's stipulation that the public should be admitted free, were chiefly concerned with the safeguarding of the exhibits.

In the course of time public access to the museum became less restricted: but it was not until 1810 that all persons "of decent appearance" were admitted on three days a week, and the only thing required of them was their signature in a book. They were now permitted to inspect the exhibits as long as they wished, and the appreciation of the public was expressed in many letters to the Press. This was the beginning of the freedom now almost universally enjoyed by the public in visiting museums.

The French Revolution also gave an important impetus to the public museum movement, for with the overthrow of the monarchy, the valuable and extensive collections of works of art in the royal palaces were made accessible to the citizens. The palace of the Louvre in 1793 became the Museum of the Republic. In Spain a national museum of natural history had been opened to the public seventeen years previously.

The British Museum, the Natural History Museum of Paris, and certain other European museums were established during the latter half of the eighteenth century when the systematic study of nature was being developed and the foundations of the modern sciences of botany, zoology and geology were being laid. Museums were soon found to provide the most suitable places for the preservation of the specimens and collections which was leading to the advancement of knowledge; and it became customary for those engaged in such scientific pursuits to entrust to these institutions for safe keeping the material upon which their investigations were based. In this way, one of the chief purposes for which museums exist, namely, conservation, received considerable attention.

The gradual accumulation of collections of this kind led to investigators resorting more to museums to study this material, and to take there for comparison and investigation any new material that came into their possession. Consequently, museums came to be increasingly recognised as institutions for investigations where scientific research could be carried out by visiting scientists, in addition to such work by members of the scientific staff.

As public museums developed, it became customary to classify the collections and arrange them in a systematic manner; but they were usually displayed in their entirety and visitors were greeted with serried rows of similar specimens, which if labelled bore no information of interest to the ordinary visitor. There was no attempt to display the collections so that persons who had made no special study of the subject could profit from them; and the student or research worker was at a serious disadvantage in not being able to examine and compare specimens closely.

About the middle of the nineteenth century, however, when great interest was being taken in education, and the advantage of general education for the masses was beginning to be appreciated and even demanded, the important part that museums were capable of playing in public instruction came to be recognised. Henceforth, more and more attention was paid to making the exhibits instructive; and so, in addition to being repositories of objects of scientific, historical and cultural value and centres of scientific research, they became important educational agencies.

The collections in the natural history museums came to be divided into two distinct series: One, the study or reference series, consisting of the majority of specimens, was intended for the use of scientists and students and was not exhibited to the public; and the other, the exhibited series, was intended for public education. This principle of displaying a selected series and storing the remander has since been adopted by museums

devoted to archaeology, ethnography, history, art and other subjects.

There has been a great advance during the last thirty years in the methods of display and in the art of taxidermy. The best principles in use by window dressers for the display of goods in stores, and by those employed in exhibits at international exhibitions have been successfully adopted by the more progressive museums in America and Britain. The display of natural history exhibits has culminated in what is known as the "modern habitat group," in which a group of mammals, for instance, is displayed amongst natural surroundings that are faithfully reproduced and made to merge imperceptibly into a semicircular, painted, scenic background, with concealed internal illumination, adopting the principles employed in the diorama. The same type of exhibit has been employed for ethnographic exhibits, where the habits and mode of life of native races are demonstrated by life-like models, or casts from life, of individuals engaged in their everyday occupations.

In modern museums exhibits are made to teach subjects in a more direct and convincing way than textbooks. The illustrations in a textbook are merely substitutes for the actual things referred to, but in museums the position is reversed, for there actual objects replace the illustrations and informative labels take the place of the reading matter of the book.

By the employment in natural history museums of group exhibits in which carefully selected specimens are arranged according to a definite underlying plan and are supplemented by explanatory diagrams, photographs, models and informative labels, principles are demonstrated, ideas conveyed, and an interest aroused that creates a desire to learn more about the subject, to meet which handbooks containing fuller information than that on the labels are usually provided.

By these means, museums have become institutions of visual instruction, great popular educators, with their carefully selected specimens and intelligently displayed exhibits, accompanied by informative labels and supplemented by the provision of official handbooks.

The educational influence of museums that have not advanced beyond this stage is, however, limited to those who take the trouble to read the labels and study the exhibits seriously. During the last twenty-five years it has been found that museums can be changed from this passive condition and made active educational forces of almost unlimited influence. Following the American example and owing to the persistent efforts of the late Lord Sudley in the House of Lords, guide-lecturers were appointed to the national museums of Britain in 1920, and soon the innovation was adopted by all the principal museums throughout the country. It has since spread to other parts of the world, including South Africa.

In Britain and America there has been for many years active co-operation between the museums and the education authorities in two directions, namely, by encouraging the visits of school children to the museums for instruction and by providing loans to schools.

The manner in which the visits of parties of school children are organised and carried out varies according to the local conditions and the facilities available. In some cases a member of the museum staff is responsible for the work; but in others the education authorities appoint a suitable qualified teacher for carrying it out. The other form of service rendered to schools consists of the loan of museum material for use as visual aids during instruction. Some museums possess extensive collections of lantern-slides and motion films which are similarly available for borrowing by the schools; and in the case of some of the large museums in America a fleet of motor vans is kept constantly employed delivering and collecting the material loaned to schools.

The delivery of formal public lectures by members of the museum staff or by other qualified persons on subjects within the scope of the institution, or related to them, is now a recognised activity; and many museums have a properly designed lecture hall incorporated in their building, with the necessary equipment for showing motion films and lantern slides. Regular monthly or weekly lectures, sometimes in courses, are given in some museums; and printed syllabuses are distributed periodically. By this means museums can be of considerable service in the interests of adult education.

Hitherto, I have been dealing principally with museums and education, the diffusion of knowledge. Let me now refer to them in relation to their other chief function, namely research or the advancement of knowledge. And in this connection I shall confine my remarks largely to one institution, the British Museum because it is the oldest and most famous of museums and because I am familiar with it.

Certain subjects such as archaeology, ethnography, zoology, botany and palaeontology are particularly indebted to museums, both for their present advanced condition and for the constant extension of their boundaries by research conducted in museums by members of the staff and by other investigators. Archaeology, both classical and prehistoric, owes an inestimable debt to museums, for practically all the products of importance obtained by the excavation of ancient sites during many years are preserved in public museums; and many of the most famous of these excavations have either been made by members of museum staffs or supported by museum authorities. Had time permitted, I would have directed your attention to the vast store of classical and prehistoric archaeological material in the British Museum; the valuable research work carried out; and the important official

publications issued by the Museum embodying the results of that research. But I shall have to confine my remarks to the natural history departments, comprising the zoological, botanical, palaeontological and mineral collections, which are accommodated in a building erected for the purpose at South Kensington in 1880.

The zoological collections alone number more than ten million specimens. They include some 90,000 mammals, 750,000 birds, 75,000 reptiles, 150,000 fishes, 700,000 molluscs and 8,500,000 insects. Thousands of additions are made annually, and are acquired by donation, by purchase, or are obtained on collecting expeditions undertaken my members of the staff and others on behalf of the Museum. The great value of these collections lies in the work that has been done upon them by the members of the scientific staff and by other qualified persons. They include a great many "types," the original specimens upon which new species have been founded, and specimens of historical scientific interest; and they are the subjects of many monographs, catalogues and other scientific publications.

The scientific work that is carried out is mainly that known as systematics or taxonomy, i.e., the naming of species and their classification in a natural system that indicates true relationship. This work is essential as the foundation for all other branches of scientific work relating to zoology and botany. Although it is of the nature of pure science, the knowledge thus obtained is constantly being applied to medicine and public health, and to agriculture and other industries.

The principal scientific publications of the zoological department are the catalogues of the various collections. These are not merely lists of the species represented, they deal with all known species of the particular group. For instance, the catalogue of birds alone comprises twenty-seven volumes of an average of 500 pages each; and in the case of every known species a full description is given, with references to previous literature dealing with it, a full synonymy, an account of the known distribution, and a list of the specimens by which the species is represented in the museum collection; in addition to which descriptions of the genera, families and orders are given and keys furnished to assist in the naming of a specimen. They are authoritative works, in which all scientific knowledge of a taxonomic nature concerning the group at the time of publication is included. They are indispensable to ornithologists working in similar institutions in any part of the world.

Similar catalogues of other groups of the animal kingdom have been published at various times. That relating to snakes comprises three volumes that were published between 1893 and 1896. The eight volumes of the first edition of the catalogue of fishes have been out of print for some time; but the first volume of a second edition was issued in 1895. A catalogue of

moths, occupying thirteen volumes, was published between 1898 and 1913; and a monograph of mosquitoes, the publication of which was completed in 1910, required five volumes to accommodate the descriptions and other information relating to the several hundred then known species. I have referred to only a few of the many published catalogues; but it is sufficient to indicate the vast output of scientific work of this nature from a single department of one museum and it has to be borne in mind that the scientific staff of zoologists is also employed in naming and incorporating accessions, describing new species, and writing papers based upon sections of the groups under their charge, which are published in suitable channels, such as the journals issued by the zoological, ornithological, entomological, malacological and conchological societies and the *Annals and Magazine of Natural History*.

The collections of the department of geology are restricted very largely to fossil animals and plants. They number many hundreds of thousands and in one year alone the acquisitions may amount to over eight thousand. The mineral collection numbers about a quarter of a million specimens; and the herbarium of the botanical department in 1922 comprised approximately four and a half million preserved specimens of plants from all parts of the world, additions to which in normal times exceed an annual average of 100,000 specimens. The scientific work carried out in the geological and botanical departments is of a similar nature to that described in regard to the zoological department, i.e., it consists essentially in the naming and classification of species.

In addition to the catalogues and other scientific publications, guide-books to all the various sections of the Museum are available for the use of visitors inspecting the exhibits; and a number of useful booklets on economic subjects have been published, such as "Furniture Beetles, Their Life-history and How to Prevent the Damage Caused by Them"; "Marine Boring Animals Injurious to Submerged Structures"; "Birds Beneficial to Agriculture"; "The Biology of Waterworks"; "Mosquitoes and their Relation to Disease" and "The House-fly as a Danger to Health."

I have endeavoured to indicate the services rendered to the advancement of science by reference to one museum alone; but it must be borne in mind that similar services are being carried out in the national museums of countries throughout the world; and to a less extent by many other museums that are not of national status.

Let me now direct attention to the museums of South Africa and indicate what they are doing in that direction. The first public museum to be established in this country was the South African Museum, Cape Town. For long it was believed that it dated from 1838, when the Literary and Scientific Institution

undertook the formation and maintenance of a museum amongst its activities; but Professor P. R. Kirby has recently established the fact that Dr. Andrew Smith founded the museum in 1825. Under the successive curatorships of E. L. Layard from 1855 to 1872, Rowland Trimen from 1872 to 1895, of W. L. Sclater from 1896 to 1906, and L. Peringuey from 1906 till his death in 1924, the museum's record was one of continuous growth of collections and advancement in scientific status. And this splendid record has been well maintained under their successors, Dr. E. L. Gill and Dr. K. H. Barnard. Layard was the author of the first comprehensive work on the birds of South Africa (1867); Trimen of three volumes on South African butterflies (1887-9); and Sclater of two volumes on the mammals of South Africa (1900) and, in conjunction with A. C. Stark of four volumes on the birds of South Africa (1900-1906), all of which have become standard works, while a well-illustrated "First Guide to South African Birds" by Gill was published in 1936.

In 1892, while Peringuey was assistant curator, the first portion of his work "Descriptive Catalogue of the Coleoptera of South Africa" was published in the *S.A. Philosophical Society's Transactions*, and further portions appeared in the same publication during the succeeding fifteen years, covering more than 2,500 pages in all. Although he was never able to complete this vast undertaking, he continued to publish papers dealing with various portions of the extensive collection of coleoptera as well as other collections belonging to the Museum. In 1908, the Museum's scientific publication, *Annals of the South African Museum*, made its appearance; and during the succeeding period of thirty-seven years, thirty-two volumes, having an average content of between 500 and 600 pages were completed, and other volumes are in course of publication.

The hundreds of articles that these volumes contain are chiefly of a taxonomic nature relating to various groups of the fauna of South Africa, and while the majority embody the results of work by members of the scientific staff on the groups under their charge, others are by specialists overseas or in South Africa to whom portions of the collection have been entrusted for critical examination and report. But the *Annals* have by no means been restricted to contributions relating to the fauna, for many deal with South African palaeontology, botany, anthropology and ethnology, and are similarly based upon the extensive study of collections belonging to the Museum. Amongst the most important works published in these *Annals* may be mentioned a monograph on the ants of South Africa by George Arnold, occupying 766 pages; a monograph on the marine fishes of South Africa by K. H. Barnard occupying 1,065 pages; the first portion of a revision of the Bombyliidæ (a family of two-winged flies) of South Africa by A. J. Hesse; a monographic survey of South African non-marine molusca by M. Connolly;

the Stone Ages of South Africa, as represented in the collections of the South African Museum, by L. Peringuey—a work that laid the foundation for the study of prehistoric archaeology in this country; and the Stone-Age cultures of South Africa by A. J. H. Goodwin and C. van Riet Lowe. The *Annals of the South African Museum* has maintained a high standard from its first appearance, both as regards the printing and the scientific value of the contents of its thirty-two volumes. It reflects great credit upon the Museum, and especially upon the scientific staff whose labours it records; and the scientific information embodied in it is of national value and of international scientific interest. For the use of visitors the Museum has published a short general guide-book to the exhibits and special handbooks devoted to the insect exhibits, the post office stones, and the exhibits relating to the stone-age. It operates a well-organised service of loans to schools. The South African Museum forms one of the four national museums, for the financial support of which the Union Government is responsible, the others being the Transvaal Museum, Pretoria, the Natal Museum, Pietermaritzburg, and the National Museum, Bloemfontein.

The Transvaal Museum was founded as the State Museum by the Government of the South African Republic in 1892. In addition to the exhibits that are displayed in its spacious galleries it possesses extensive study collections of South African mammals, birds, reptiles, amphibians, insects and other invertebrates, plants, and archaeological and ethnographical material. The first part of its scientific publication, *Annals of the Transvaal Museum*, was issued in 1908; and since that year twenty volumes varying in size from 135 to 612 pages have appeared. They contain monographs and other articles chiefly of a taxomic nature and mostly written by members of its scientific staff, which consists of a mammalogist and ornithologist, an entomologist, a palaeontologist, a botanist, and an official in charge of lower vertebrates and invertebrates, excluding insects. But the largest single contribution is a monograph of the Sphegidæ of South Africa, by G. Arnold of the National Museum of Southern Rhodesia, occupying 864 pages and containing descriptions of 324 species new to science.

In 1943, this Museum published "The Lizards of South Africa" by Dr. V. Fitzsimons, who has charge of the lower vertebrates and invertebrates, exclusive of insects. It is a comprehensive work, with descriptions of 276 species, together with bibliography, distribution and habits, and is based upon a study of the material in all the museums of South Africa and in the British Museum and the Royal Scottish Museum, Edinburgh. Dr. Austin Roberts, who has charge of mammals and birds, is the author of a volume on the birds of South Africa, a scientific and practical handbook dealing with all species known to occur south of the Zambezi and Cunene rivers, the majority

of which are illustrated with excellent coloured figures. It has done a great deal to promote interest in birds throughout the country; and so successful has been its sale that although several editions have been printed, the demand is constantly outstripping the supply. The work being carried out by the scientific staff of this museum is, like that of the South African Museum, of a high standard.

The Natal Museum, Pietermaritzburg, had its origin in the activities of the Natal Society, which in 1879 decided to form collections of natural history with a view to establishing a museum in connection with its library. In 1903 the Natal Government agreed to take the museum over; and nineteen years later the Union Government assumed full responsibility for its maintenance. Its scientific activities are recorded in the numerous reports and treatises that have been published in ten volumes of *The Annals of the Natal Museum*, the various parts of which have appeared from time to time since 1906. These scientific articles have chiefly dealt with zoological, botanical, geological and ethnological subjects, especially in relation to the province of Natal and Zululand. Many of the contributions are of a taxonomic nature; but there are botanical papers of an ecological nature by J. W. Bews, and morphological and embryological papers by Ernest Warren, who was director of the Museum from 1903 to 1935, and who was responsible for setting the high standard of the printing and the contents of this scientific publication and for organising and developing the Museum according to the best accepted principles.

The National Museum, Bloemfontein, was founded in 1877 at a public meeting of residents. Since 1881 it has received annual government grants for its maintenance; and in 1922 the Union Government constituted it one of the four national museums. Under the directorship of Dr. E. C. N. van Hoepen, it has become an important centre of palaeontological research; and since the first part of its scientific publication was issued, in 1928, thirty-nine articles relating to zoological, palaeontological and archaeological subjects have appeared, under the authorship of its director and of his assistant, Dr. A. C. Hoffman.

The Albany Museum, Grahamstown, is one of five general museums in the Cape Province whose principal financial support is derived from the Cape Provincial authority. It was founded in 1855 by the Eastern Province Literary, Scientific and Medical Society. Under Dr. S. Schönland, who was director from 1889 to 1910, and his successor, Dr. J. Hewitt, the collections have constantly increased in number and importance and the Museum has become recognised as an important centre of research. A scientific publication, *Records of the Albany Museum*, has been issued at irregular intervals from 1903. Amongst the Museum's possessions is an extensive herbarium in which plants of the Eastern Province predominate. In addition to a general guide-

book to the exhibits, a Guide to the Fauna of the Albany District has been published. The Museum operates a schools loan service which circulates loan material to schools over a wide area and is conducted by a teacher seconded for the purpose, by the Provincial Education Department.

Efforts to form a museum at Port Elizabeth by various cultural societies date from 1856; but it was not until 1885. when the City Council decided to take over the museum of the Athenaeum that such an institution was established on a permanent basis. From 1887 it has been in receipt of an annual grant from Government. During the period 1906 to 1936, when Mr. F. W. FitzSimons was director, a great deal was done to popularise the Museum; and in 1919 he established in connection with it the first snake park in South Africa. In 1942 the Cape Education Department seconded a teacher to the Museum for the purpose of giving lectures and demonstrations to visiting classes from the local schools.

The McGregor Museum, Kimberley, was established by Mrs. Margaret McGregor in memory of her husband, Alexander McGregor; it was first opened to the public in 1908. Its exhibits and study collections chiefly relate to the fauna, flora, archaeology, ethnography and history of Griqualand West and Bechuanaland. With the aid of grants from the Carnegie Corporation of New York, the Museum has published a series of volumes on the Bantu tribes of South Africa, which consist chiefly of reproductions of the excellent photographs taken by Mr. A. M. Duggan-Cronin.

The Kaffrarian Museum, Kingwilliamstown, was founded by the local Naturalists Society in 1884. In addition to the exhibits, it possesses a very extensive study series of South African mammals, collected by its Director, Capt. G. C. Shortridge on many expeditions he had undertaken. He is the author of two volumes on the mammals of South West Africa that were published in 1934.

The East London Museum was opened to the public in 1921; and its collections were transferred to the present building about ten years later. Amongst its exhibits is the Cœlacanthid fish, *Latimeria Chalumnæ*, a surviving representative of a group that has been extinct since the Cretaceous period. This has brought some fame to the institution.

The Durban Museum, a municipal institution, was first opened to the public in 1887, in a room in the former Town Hall, the present central post office. The collections were removed to their present quarters in a portion of the City Hall in 1910. In addition to the exhibits, which are displayed in such a manner as to make them of the greatest educational value, it possesses study collections of insects, including the Barker collection of 12,000 South African coleoptera, and other groups. From 1910

to 1922 the Museum was in receipt of a grant of £650 from the Union Government and it issued a scientific publication, the *Annals of the Durban Museum;* but the grant was withdrawn in 1922 and the onus for further publications fell upon the Natal Provincial authority. Representations made to that body on various occassions met with no success and the publication has been largely suspended. There is a guide-lecturer on the staff who, amongst other duties, gives talks to visiting classes of school children daily; educational films are shown to children on Saturday mornings; and a schools loan service is in operation. Two editions of an illustrated guide-book to the exhibits have been published.

An excellent example of a private museum in South Africa will be found in the collection of South African lepidoptera belonging to Mr. A. J. T. Janse of Pretoria. That collection, which numbers many thousands of specimens, is a well accommodated and cared for as it could be in any public museum; and the scientific work that Dr. Janse is carrying out in connection with it is of the very highest standard. He has undertaken a stupendous task in writing a work on the moths of South Africa, on the lines of the British Museum catalogues. The first three volumes were published between 1932 and 1939 and the fourth volume is in course of publication. It is to be hoped that he may live to see his great work completed.

I trust that I have succeeded in indicating, though I fear very inadequately, the services that the museums of South Africa and particularly the national institutions, are rendering in the advancement of science. It is, as I have pointed out, principally of a taxonomic nature, a type of work that is very little appreciated by the general public. But it is essential as the basis for all zoological and botanical work, whether embryological, anatomical, ecological, or physiological; it is a necessary preliminary to the work of the economic biologist, economic botanist, and marine biologist; and also in connection with much medical and veterinary research. A great deal has been accomplished; but very much remains to be done; and in order that the work may be carried on at a greater pace the museums require more funds for the engagement of additional scientific staff, for the printing of their scientific publications, and for undertaking collecting expeditions.

In conclusion, I propose to refer to the organised co-operation of museums for their mutual benefit and for the advancement of museum services generally. The first organisation of that kind was the Museums Association established in Great Britain in 1890. Seventeen years later America followed Britain's example; and similar bodies have been set up since in most countries, including South Africa.

In 1927, an International Museums office was established in Paris in connection with the International Institute of

Intellectual Co-operation under the aegis of the League of Nations. It published a periodical " Mouseion "; and in 1935 it published a two volume work on the architecture and arrangement of art museums, and I believe intended to publish a similar work relating to science museums. Its activities have been suspended during the war; but it is hoped that in the various peace discussions provision will be made for this organisation to resume its activities.

In 1932, the late Sir Henry Miers, and Mr. S. F. Markham, then president and secretary, respectively, of the Museums Association of Great Britain, visited South Africa on behalf of the Carnegie Corporation of New York in order to ascertain the position of the museum and art gallery service of the Union and to suggest improvements. They visited all our museums and art galleries and subsequently submitted to the Corporation a report which was widely circulated. In that report they called attention to the lack of a single museum in the country dealing specifically with industry or with agriculture; and in referring to the absence of a scientific museum in Johannesburg, they stated that " The departmental museums of the University of Johannesburg, although well cared for and containing much interesting material, are not yet public museums in the strict sense of the word. This lack of a good scientific museum in Johannesburg is perhaps the greatest gap in the present museum service of the Union. . . . There are, however, indications that in the University and elsewhere this fact is realised, and it is hoped that plans for a really good public science museum will materialise in the near future." Three important general requirements in the museums service of South Africa were emphasised, namely, greater financial security; some form of active co-operation between all museums; and the development of educational work. Financial security was a matter for the Union, Provincial and Municipal Governments, but the appointment of a Government commission was suggested to enquire into the whole system of museums and to indicate definitely where financial responsibility should rest.

As regards the last two requirements, it was suggested that the Research Grant Board should be invited to administer any funds that might be obtained for experiments over a three-year period for the creation of a Museums Association of South Africa; for the preparation and publication of a text-book dealing with curatorial problems in the sub-tropics; for the selection of museum and art gallery curators or principal assistants to visit European and American institutions under the visiting grants scheme of the Carnegie Corporation; and for the initiation of educational schemes in selected areas of the Cape Province. Sir Henry Miers and Mr. Markham concluded their report by stating how impressed they were by what had been done on very small budgets, and the conviction that with vigorous and sympathetic co-operation between all museums and educational

authorities, South Africa would be able to explore and display the enormous scientific treasures at her doors and develop a museum service which would be the admiration of the world. A year or two after the issue of that report the Carnegie Corporation of New York allocated a substantial sum of money for the benefit of museums of the Union; and from that fund grants were made over a three-year period for various purposes, including the creation of a Museums Association of South Africa; the appointment of a guide-lecturer at the Durban Museum, as a demonstration of the advantage of the guide-lecturer service; and the inauguration of schools loan services at the South African Museum, Cape Town, and at the Albany Museum, Grahamstown.

The South African Museums Association was formed in 1936 and has amply justified its existence. By means of a quarterly periodical and general meetings of members in different towns every year, the distances between the museums have been bridged, and the co-operative efforts of members have been employed in solving general and individual problems. When conditions permit the South African Association for the Advancement of Science again to hold annual general meetings in different centres, it is hoped that they may be held in conjunction with the meetings of the Museums Association, as occurred in Johannesburg in 1941.

The guide-lecturer service has been permanently established at the Durban Museum and guide-lecturers have since been appointed to the Port Elizabeth Museum, the National Botanic Gardens at Kirstenbosch and the National Zoological Gardens, Pretoria; and other museums are considering the appointment of such officials. especially for dealing with visiting classes of school children.

The school loan services at the Albany Museum, Grahamstown, and the South African Museum, Cape Town, have also been successfully and permanently established; and a similar service has been organised at the Durban Museum.

Prior to 1935, practically all the museums of South Africa were of similar scope; being predominantly natural history museums but embracing archaeology, ethnography and to a limited extent local history. But with the establishment of the Africana Museum at Johannesburg in that year a distinct hiatus in the South African museums service was filled, a lack that was apparently unobserved when the Miers and Markham report was written. It is true the Voortrekker Museum, Pietermaritzburg, and the Koopmans de Wet historic house, with period furniture, at Cape Town, were in existence; but there was no museum that embraced the whole history of South Africa within its scope as does the Africana Museum, which by the wealth of original material it possesses and the excellent manner in which it is displayed and labelled reflects the greatest credit upon the Johannesburg City Council and those responsible for its establish-

ment and development. It is gratifying to know that serious consideration is being given at the present time to the question of establishing a general science museum and an industrial museum at Johannesburg, the lack of which was mentioned in the Miers and Markham report.

As regards the establishment of an agricultural museum, to the desirability of which the Miers and Markham report also directed attention, I understand that in plans that were drawn up just before the outbreak of war for a proposed building to accommodate all sections of the Department of Agriculture and Forestry in Pretoria, provision was made for an institution of this kind.

In addition to these proposed new museums, which it is hoped will soon materialise, several museums are considering the erection of new buildings, and others intend to build extensions as soon as circumstances permit. So the next few years should see considerable development in the museums service of South Africa; and as the advantage of instruction by visual means is being more and more recognised, there is no doubt that our museums are destined to play an ever increasing part in adult and juvenile education.

South African Journal of Science, *Vol. XLII, pp. 18-28, June, 1946.*

THE CONTRIBUTION OF VARIABLE STAR RESEARCH TO THE PROGRESS OF ASTRONOMY

BY

Dr. H. van Gent,
Leyden Observatory Southern Station, Johannesburg.

Presidential Address to Section A of the South African Association for the Advancement of Science.

Read 3rd July, 1945.

It is my task this morning to sketch, in a rough outline, the part that variable star work has played in the development of Astronomy.

The name "variable star," now in use for a century or two, was not too happily chosen, as it does not state what it is that varies in such a star. Although in this address no attempt will be made to replace it by a better term, it should be remembered that whenever the term "variable" or "variable star" is used, a star with variable brightness is meant.

There is no doubt that the first stars of variable brightness to be discovered were Novae. The name Nova has also not been chosen too happily, as such a star is not new at all, but is an old star which has had a great and very special increase in brightness. One can understand the choice of this name, however, if one realises that before the invention of the telescope all observations of stars had to be made by the naked eye. Practically all Novae are invisible to the naked eye before their increase in light and they sink back into invisibility some time after their maximum, so that they can only be seen during a short period. The brightest Nova ever discovered is probably Nova Tauri 1054, which became much brighter than Jupiter and was visible in daylight. It is practically certain that this Nova is responsible for creating the well known Crab Nebula in Taurus. Two other daylight Novae were Tycho Brahe's Nova in Cassiopeia of 1572 and Kepler's Nova of 1604 in Ophiuchus.

The first discoveries of variable stars other than Novae soon followed. In 1638, *o* Ceti was found to be a variable by Professor Holwarda of the University of Franeker in the Netherlands; in 1667 β Persei (Algol) was found to be variable by Montanari, and from then onwards many variables were discovered, at first among the brighter stars and later among the

telescopic stars. These discoveries reflect the rise of public interest in Astronomy caused by the need for knowledge about the stars for navigation purposes in the 17th century.

By that time all stars visible to the naked eye had been named by Bayer with Greek and small Roman letters, according to constellation, and a second system of designation, using numbers instead of letters, but also according to constellation, had been introduced by Flamsteed. In so far as the newly discovered variable stars were naked eye stars no new names were necessary for them: they could be indicated either by their Bayer name or by their Flamsteed number. For the fainter variables, however, some system of naming became desirable. It was, at that time, not realised that the number of variables would grow out of all proportion later on, and a system of naming was chosen which later had to be repeatedly amended. It is of interest to recall these naming difficulties, as they show the importance of choosing a good naming system at the beginning when one has to catalogue an ever increasing collection of objects. The system of naming chosen for variables, mainly at the instance of Professor Argelander of the observatory at Bonn, Germany, was to give them a Roman capital letter from R to Z, followed by the name of the constellation in which the stars occurred. This made nine names available per constellation, which was considered ample as long as variable stars were thought to be curiosities of which a very limited number existed. When the available nine places per constellation were used up by further discoveries, the lettering RR, RS, etc., SS, ST, etc. to ZZ was taken, and then the further lettering AA, AB, etc., BB, BC, etc., till QQ was used. Even this proved insufficient in some very rich constellations like Cygnus, Centaurus, and Sagittarius and the step which should have been taken at the beginning was finally adopted, simple numbers being given to the variables after QQ, starting with V335—(V for variable), followed by the name of the constellation. Tradition had, however, become so strong, that the old nomenclature up to QQ, etc., was retained, and we are still saddled with a heterogeneous and inelegant way of naming and numbering the variable stars.

The number of variables has now risen to 8,445, according to the latest catalogue available here. This catalogue was formerly issued every year, and brought up to date by one of the German observatories. It really consists of two catalogues of the whole collection, one according to constellation, the other according to Right Ascension, that is, according to the star's position in the sky. It contains bright stars as well as faint ones, from the first down to 16th and 17th magnitude. Although it contains all the information up to date, it is far from complete or homogeneous, as a true representation of what really is present in the sky, and any statistician using the catalogue should bear this in mind. That is not the fault of the compiler,

but is due to the contributions for this catalogue coming from so many different observers, working with different telescopes and obtaining their results from different pieces of work and even from searches for proper motion stars and minor planets. Whereas in the early days all discoveries were accidental and made visually, the later discoveries have mostly been made photographically and are partly accidental and partly the result of systematic searches. The systematic discoveries on the photographic plates are carried out by comparing plates covering the same region of the sky but taken at different times. The Harvard observers prefer the method of superposing a negative on a positive of another plate of the same region; nearly all other observatories compare the plates by pairs in the blink microscope. By repeating the procedure with different pairs of plates of the same region a certain degree of exhaustion of the available population of variables can be reached, but very few observers have determined that degree of exhaustion as a percentage of completeness, although this percentage can be found without much trouble from the recurrence of the same variable objects in different comparisons. As a result the catalogue of variable stars is reasonably complete for the brighter stars, but very incomplete and heterogeneous for the fainter ones. One may find portions of the sky which have been thoroughly searched say to the 15th magnitude adjacent to fields into which practically nobody has ever looked. It is remarkable how some naked eye variables have been able to escape detection. As an example the variable β Doradus may be mentioned, easily visible to the naked eye, which shows fluctuations in its brightness of over 200 per cent., in periods slightly less than 10 days. This star was discovered to be a variable as late as 1927, and that only because the radial velocity observers drew attention to its peculiar radial velocity curve. It is a reasonable assumption that quite a number of naked eye variables are still undetected. Among the approximately 5,000 stars in the sky visible to the naked eye there are 47 variables known, so that variability occurs in about one star in a hundred. It is interesting to compare this datum with the corresponding one for visual double stars, which is about one double in every 17 stars.

I now have to say a few words about the scale of brightness used by astronomers. Some physicists are dissatisfied with this scale, and especially with its logarithmic nature. They ask: why do not astronomers use the ordinary physical units of candles for absolute brightness, and metrecandles or lux for the apparent brightness, that is, for illumination. The answer is that the astronomer's choice is due to the power of the human eye to perceive and judge the ratio of the intensities of two lights more clearly than their difference. Therefore a ratio, and not a difference of brightness was taken as unit in stellar photometry. The ratio of two lights differing by one

magnitude and corresponding to a difference of 0·4 in the logarithms of their intensities, was introduced in 1850 by Pogson, mainly to make the brightness of the stars agree as closely as possible with those of the first catalogue of naked eye stars—Ptolemy's Almagest. Consequently a ratio of one to one hundred in the intensities corresponds to a difference of five magnitudes in brightness. To facilitate transformation of the two systems of photometry into one another the following conversions at different points of the scale may be mentioned: in the astronomical scale the apparent brightness of the sun is $-26{\cdot}7$ magnitudes, corresponding to 135,000 metrecandles; of the full moon $-12{\cdot}5$ magnitudes, corresponding to one fifth of a metrecandle; a star of the brightness of 0·5 magnitudes, like α Centauri, corresponds to one millionth of a metrecandle, and a star just visible to the naked eye corresponds to one hundred millionth of a metrecandle. Incidentally, these data give an idea of the very great difference in brightness which astronomy has to handle, another reason for choosing a logarithmic scale rather than a linear one. A few equalities in the other direction may be mentioned: one metrecandle corresponds to a brightness of $-14{\cdot}2$ magnitudes and a candle at a distance of ten kilometres corresponds to a star of 5·8 magnitudes, which is barely visible to the naked eye. As to the energy received from the stars, the sun gives an energy of 1·94 calories per minute per square centimetre; for a sixth magnitude star the quantity is 1·6 times 10^{-13} calories; if expressed in photons per second this quantity becomes 31,000. Estimating the pupil of the eye to have an area of one third of a square centimetre at night, this corresponds to approximately 10,000 photons per second in the eye for the faintest stars visible.

I now turn to the part that variable stars have played in determining distances in our own Galactic System, and also outside it. The fundamental method of determining distances of stars is by measuring their trigonometric parallax, that is their apparent displacement in the sky due to change of position of the earth in its orbit round the sun. The base line in this triangulation is the diameter of the earth's orbit. The number of individual stars for which distances have been determined in this way is now several thousand. For the southern sky a great portion of this work has been carried out by Dr. Alden at the Yale Observatory Southern Station in Johannesburg. This method of distance determination is the basis for all further methods, which are checked and calibrated by it. The unit of distance used in these measures is the parsec, that is the distance at which the earth's orbit round the sun appears as a small ellipse with a semi axis major of one second of arc. The parsec corresponds to 3¼ light years. The parallax of the nearest star, α Centuari, is 0·76 seconds of arc, corresponding to a distance of 4¼ light years. Big as this distance is compared with distances on the earth, it is insignificant with respect

to the dimensions of the Milky Way System, which is thought at present to have a diameter of some 100,000 light years.

The beginning of the use of variable stars as distance indicators may be found in the discovery, by Miss Leavitt, of the Harvard observatory, of the remarkable relation between the apparent brightness and the periods of variable stars of the δ Cephei type in the Small Magellanic Cloud. The variables of this type are characterised by the following peculiarities in their light fluctuations. The fluctuations occur in strict periods, which run from one third of a day to more than a month for the different variables, each variable adhering strictly to its own period. The rise in brightness for such a variable is rapid, occupying only about one tenth of the period; during the remaining nine tenths of the period the star slowly drops back to its original brightness. At maximum these stars are about three times as bright as at minimum. The longer the period, the brighter the star. The relation found by Miss Leavitt is important because it indicates that to a certain period of light variation there belongs a definite value for the average candle-power of the variable. As soon as this candlepower, or absolute luminosity, is known, the variable can be used for distance determination, by comparing its absolute luminosity with its apparent brightness in the sky. The task of determining these absolute luminosities for some twenty variables of this type, not in the Small Magellanic Cloud, but in the Milky Way, was performed by Professor Hertzsprung, now director of the Leyden Observatory in the Netherlands. He chose the brightest ones available, that is, nearest to our sun, in order to determine their distances. Unfortunately all these stars are too far away for accurate direct determination of their distances by the ordinary trigonometric parallax method. Therefore an extension of the ordinary trigonometric method, the so-called method of secular parallaxes, had to be used. This method uses a much longer base line, provided by the sun's motion between the stars at a speed of 20 kilometres per second in the direction of the constellation Hercules. Statistically this gives good results, but for individual stars the values obtained may be subject to considerable error. By this method the distance of the Small Magellanic Cloud was found to be 100,000 light years. For the Great Magellanic Cloud the value 110,000 light years was obtained later. With this penetrating tool the dimensions of our Milky Way System have also been determined. The size of this system can now perhaps best be described as follows. It is a disc-like agglomeration of some 30,000,000,000 stars, stretching over a distance of about 100,000 light years from end to end. The thickness of the disc in the middle is about 15,000 light years. These figures have not been obtained without difficulty, most of which is caused by patches of dark matter, especially in the plane of the Milky Way, which dim the light of stars behind them and falsify the result of the photometric

distance determinations if no appropriate correction is applied. The total mass of the Milky Way System, stars and dark matter together, is estimated at 200,000 million times the mass of our sun.

The method of determining distances by variable stars reaches even further than the boundries of the Milky Way System. Far outside our own Milky Way System lie the spiral nebulae, and as soon as variable stars of the δ Cephei type were found in the nearer ones, a determination of their distances became possible. In this way the distance of the Andromeda Nebula was found to be 950,000 light years, or nearly ten diameters of the Milky Way System away from us. For a few other nearer nebulae, distances have been determined in the same way, but here we are at the limit of the possibilities of our method, as the variable stars can only be found on photographic plates taken with very long exposures with the biggest modern telescopes. For spiral nebulae still further away one has to use still brighter objects as distance indicators. Fortunately these are available in many spirals in the form of Novae and supernovae. It is estimated that about 30 Novae occur every year in the Andromeda Nebula; they become several magnitudes brighter than the Cepheid variables, but their maximum brightnesses are not so homogeneous and consequently the distances determined become less reliable. In several spirals now and then a supernova occurs, which reaches a brightness eight magnitudes brighter than an ordinary nova, and allows still greater distances to be determined. The brightness of such a supernova is comparable to the integrated brightness of the whole nebula, reaching the unbelievable value of about 100,000,000 times the candlepower of the sun. Also the apparent brightness of the whole nebula is an indication of distance, and finally the red shift of the spectrum can be used. All these methods are checked and calibrated by the method of the Cepheid variables. Here we have reached the boundaries of the observable universe as far as it is in the grasp of the big modern telescopes, 150,000,000 light years away.

I now wish to say a few words about the distribution of the variable stars in the Milky Way System. All the variable stars show concentration towards the Milky Way, the nearer ones less, the distant ones more, much like the non-variable Milky Way stars. An exception is formed, however, by the cluster variables. This type owes its name to its occurrence, in great numbers, in the globular clusters. Their light variations are very similar to those of the Cepheid variables, but the period is always less than a day. Therefore the increase in light from minimum to maximum for these stars is a process lasting one or two hours only. It has been known for a long time that many of these variables occur in the sky at great distances from the circle formed by the Milky Way. Along the Milky Way circle their distribution is uneven; they are especially abundant in

the direction of the constellation Sagittarius, but very much less so in the opposite direction, that is in the constellation Gemini. This is quite different from other types of variables, which occur with equal frequency all along the Milky Way circle. The first indication of this uneven distribution of the cluster variables along the Milky Way circle was found at the Union Observatory, about 1930, when comparing the results of variable star searches in Corona Australis, not far from the constellation Sagittarius, and in the constellation Argus, near the Southern Cross. Later systematic searches, mainly by the Harvard Observatory, but also by the Leyden Observatory, have confirmed this state of affairs.

It is remarkable that the distribution of the globular clusters in the sky is very similar to that of the cluster variables. They are practically all found on one half of the celestial sphere, namely, that half that has the constellation Sagittarius as a centre. The reason for this asymmetry is to be found in the excentric position of the sun in the Milky Way System. The sun is actually nearer to the edge of the system than to its centre; its distance from the centre is about 33,000 light years. The effect of this asymmetrical position on our view of the bright band of the Milky Way should cause unevenness, but the presence of the big patches of dark matter modify the view to such an extent that the asymmetry is no longer so obvious. The great star clouds in Sagittarius, however, are still the brightest regions in the Milky Way, and could justly have been regarded as representing the direction towards the centre of the system without regard to any other considerations.

As the cluster variables are spread out in much the same areas as that occupied by the globular clusters, we may consider the question of any further relations between cluster variables and globular clusters. About 100 globular clusters are known, and those would seem to be all. Two of the southern ones are naked eye objects, namely ω Centauri and 47 Tucanae, the latter very near to the Small Magellanic Cloud. A good long exposure taken of ω Centauri with a long focus telescope presents a truly amazing sight showing a crowded heap of stars, concentrated towards the centre, occupying an area of nearly one square degree of the sky. On photographs of an 80 minutes exposure, taken with the Yale telescope in Johannesburg, the number of stars in this heap was estimated at 50,000; of these 161 stars are at present known to be variable. They occur mainly in the outer regions of the cluster, and the suggestion presents itself that the globular clusters are busy throwing their cluster variables out into the space between them. It is impossible to verify this suggestion by looking for displacement of the variables in the clusters on plates taken at intervals of many years: these clusters are too far away to show any internal motions, and I think the faintness of the variables has hitherto prevented the radial velocity observers from attacking the question.

The picture of the Milky Way given before, can now be completed as follows. Upon the flat disc of Milky Way stars a huge sphere containing the globular clusters with the haze of cluster variables in between, should be superposed, both systems having the same centre. The disc of Milky Way stars should be taken as slowly rotating about an axis perpendicular to the disc, but the sphere containing globular clusters and cluster variables should be considered as not taking part in this rotation at all or only to a smaller extent, so that the cluster variables lag behind the ordinary Milky Way stars. This lag of the cluster variables is an observed fact and takes place at the rate of about 100 kilometres per second.

There is still another class of variable stars—the Algol variables. The discovery of the first star of this class, β Persei or Algol, has already been mentioned. The variation of the light of stars of this class has the following characteristics: the star remains of the same brightness for a considerable time, suddenly the brightness begins to fall off, comes to a minimum in which it may or may not stay for some time, it then rises back in the same way as it has dropped, until the original brightness is reached again. After some time the same procedure recurs in a definite period, to which the star strictly adheres.

The explanation of this behaviour was given for Algol in 1782 by John Goodricke, namely, that the variable is a close double star system, one component of the system periodically eclipsing the other. The period of the changes in light corresponds to the period of revolution of the double star system. Essentially every double star system can be seen as a variable of this kind, the only necessary condition being that the orbital plane of the double star must pass, if produced, exactly or very nearly through the place of observation. Consequently if a catalogue of Algol variables were made by an observer situated in one of the Magellanic Clouds, it would have only a few Algol variables in common with ours, namely, those whose orbital plane passes through the sun as well as through his site of observation. The number of Algol variables known is slightly over 1,000. If the light variations are accurately observed, the orbit of the double star as well as the diameters of both bodies of the system can be computed in an arbitrary unit of length. If the speed in the orbit can be found from radial velocity observations, all the dimensions of the system become known in kilometres, and also the masses of both components. This class of variables contributes largely to our knowledge of the sizes, masses, densities and luminosities of the stars. As an illustration the data for two typical representatives of this class may be given. The Algol variable V Puppis consists of two bodies respectively 21 and 15 times as massive as the sun. Their diameters are both nearly seven times the sun's diameter; the distance between the centres is 12,000,000 kilometres or nearly

nine times the sun's diameter. They complete their revolution round each other in a period of slightly less than one and a half days. For the Algol variable YY Geminorum the corresponding data are as follows: both bodies half as massive as the sun, diameters just over half the sun's diameter, distance between the centres 2,600,000 kilometres or nearly twice the sun's diameter, and period 0·81 day or nearly 20 hours.

I now turn to the question whether the sun can be considered as a variable star. As the sun is known to have periodic increases and and decreases of activity at its surface, shown by the sunspots, it is natural to connect variations in radiation with the sunspot cycle. The measurement of the sun's radiation is the chief concern of several stations of the Smithsonian Institution. As the so-called solar constant is defined as the quantity of energy received per minute on an area of one square centimetre if there were no atmosphere, its determination involves corrections to the quantity of energy actually received by the pyroheliometer. These corrections are by no means easy, as they depend on different changing conditions in the atmosphere, and great care is taken that no atmospheric influences affect the result. The average over a long series of years is 1·94 calories per square contimetre per minute. It seems that fluctuations of one or two per cent. have been proved, and Abbott, who did most of the work, thinks that a correlation with the sunspot cycle exists. The radiation of the sun is thought to be higher at sunspot maximum than at sunspot minimum, with this limitation that if a group of big sunspots is situated near the centre of the sun the radiation is somewhat less. There is no doubt that long continued changes in the solar radiation would produce important alterations in the climate on earth, and may be responsible for having caused the ice ages. An increase of solar radiation over a long series of years would be able to cause the melting off of big quantities of ice, and one is inclined to think in this connection first of the enormously thick layer of ice covering the interior of Greenland. The thickness of this layer is estimated by some explorers at 1,000 metres, and, if completely molten down, the sea level on all the oceans would rise some five metres by it. A second consequence would be the slowing down of the earth's rotation. The extent of this slowing down can be found by computing the increase in moment of inertia of the earth caused by the redistribution of matter over the whole surface of the earth. A simple calculation gives an increase of about one in a million; consequently the length of the day would also increase by about one in a million, that is somewhat less than a tenth of a second of time. This seems nothing much to worry about, but in a year it would accumulate to 30 seconds, a quantity which certainly would not escape the astronomers. Actually errors of this magnitude in the time as given by the earth's rotation, accumulated, however, not in a year, but in a century, were detected some 20 years ago

independently by Dr. Innes, the first director of the Union Observatory, and by Professor de Sitter, then director of the Leyden Observatory. As all clocks on earth are corrected by means of the earth's rotation, an irregularity in this rotation can only be demonstrated if clocks independent of that rotation are available. Astronomy possesses several such clocks, namely, the eclipses of Jupiter's satellites, occulations of stars by the moon, meridian observations of the moon and the sun, observations of the rapidly moving planets Mercury and Venus and perhaps minima of Algol variables. As all these different clocks, independently of each other, indicated the same error in the earth's rotation, the question has been settled beyond doubt. De Sitter finds changes in the moment of inertia of the order of about one in one hundred million. This change could be produced by the melting of only 10 metres of the ice-cap on Greenland. De Sitter does not mention the melting of ice as a possible explanation, but only speaks of more deeply seated changes in the distribution of matter in the interior of the earth which might be responsible for these irregularities.

I may now conclude this address with a few words about the future of variable star work in astronomy. I have already pointed to the deplorable lack of completeness and homogeneity in the existing collection of known variables. In my opinion it would be very much worth while to carry out a systematic search for variables over the whole sky, but only to a limited depth, say 12th magnitude. Up to the 12th magnitude there are about a million stars in the sky, of which some one or two thousand could be expected to be variable. Such a search is well within the possibilities of even a small photographic instrument, preferable with a big field and a high aperture ratio. It should be supplemented by more penetrating surveys in selected areas of the sky. A plan of selected areas for all research on the structure of the Milky Way was drawn up about 1900 by Professor Kapteyn, of the Astronomical Institute at Groningen. This plan could possibly be used, perhaps with some modifications. The work would in this way be kept within reasonable limits, but the full advantages of the extension of the survey further into space would be obtained. Perhaps some extra attention should be given to the region of the Milky Way centre near Sagittarius. If in these surveys due attention is also paid to determining the completeness of the results, a much better body of information would be created from the viewpoint of the stellar statistician.

As to the different classes of variables, much increase of our knowledge can be expected from the work of the spectroscopists, as well as from increased accuracy in the work of the photometrists. This holds for all classes of variables. In the field of Algol variables more attention should be given to those with excentric orbits, especially when the line of apsides is moving, as the motion of that line may lead to important conclusions

about the internal distribution of matter inside a star. Spectroscopic observations have shown recently that at least some of the stars in Algol systems possess extensive atmospheres and that perhaps some of them have edges which are not sharp but diffuse. The computers should keep this in mind and perhaps consider some modification of their methods of orbit computation.

In conclusion, I may express the opinion that variable star work is also likely to be of much importance for obtaining knowledge about the constitution of the stars, as the continual change of conditions in variables promises to reveal more about star structure than the constant conditions in non-variable stars can do.

South African Journal of Science, *Vol. XLII, pp. 29-42, June, 1946.*

METHANE: A NEGLECTED NATIONAL ASSET

BY

H. Wilson,

Health Department, Johannesburg Municipality.

Presidential Address to Section B of the South African Association for the Advancement of Science.

Read 3rd July, 1945.

Methane is so widely distributed on the earth and is available in such prodigious amount that it constitutes one of the world's important raw materials and one which has hitherto been very largely wasted.

In this address, I propose to draw your attention to the great potentialities of methane, in the hope that focussing the attention of a group of scientists with as wide a scope as is included in Section B of this Association might lead to new endeavours to make fuller and better use of this asset.

Quantities of Methane Available.

Astronomical figures are needed to express the quantities of methane which have been estimated or actually measured in various countries.

It is not my intention to give here any world survey of the quantities but a few figures will suffice to present to you an idea of the vastness of the amounts.

In 1931 in U.S.A. 1,686,436,000,000 cubic feet of natural gas were actually marketed whilst vast unknown amounts were blown to waste. In the natural gas of North America there is about 85 per cent. methane. From one oil bearing area in Scotland 12,000,000 cubic feet of gas per day is available. From a single coal mine in Great Britain as much as 10,000,000 cubic feet of gas of 80 per cent. to 90 per cent. methane is available per 24 hours.

It has been estimated that the fuel value of the gas from the coal mines of Britain is equivalent to a million tons of coal per year.

Nearly all the methane from coal mines is at present wasted, but sufficient is already known concerning the engineering problems of tapping and collection of this gas to be able to say that if co-ordinated effort were directed to the problem, a substantial part of this gas could be recovered.

From the digestion of sewage sludge in the modern sewage works about 1 cubic foot of gas containing about 70 per cent. methane is recoverable per head of population per day, and the amount is increased by some kinds of trades waste, thus a town of say half a million population could expect to produce about half a million cubic feet of digester gas per day.

It is known that a number of micro-organisms are capable of producing methane by the breakdown of vegetable materials, and it is pretty certain that if demands arose, large amounts of methane could be produced from vegetable materials now wasted.

It is now coming to be widely held that methane may be produced by bio-chemical reduction of carbon dioxide and a very wide variety of organic substances can be utilised by micro-organisms as hydrogen donors for this reduction.

In the foregoing sufficient has been said to make it clear that methane is already available in vast amount, which amount could be greatly increased if demand arose. In this address I cannot discuss further the present or possible future methods of recovering or producing the gas, but I would repeat that technique is already worked out which would enable a vastly increased amount of methane to be recovered.

Uses to Which Methane Has Already Been Put.

Present large scale uses of Methane.

(1) Use as fuel.

Methane in admixture as natural gas has long been used, chiefly as a fuel, especially in North America, where colossal volumes are conveyed in a vast aggregate mileage of piping very long distances to towns and industrial sites, where the gas is burned for domestic and industrial use, and used in gas engines or boilers for production of power.

The high calorific value of methane (1003 BTU per cubic foot for pure methane) and of natural gas, and the large admixture of air required for complete combustion necessitate special designs of jet and burner and extra high compression ratio when used in internal combustion engines.

Although a mixture of air and methane is very easily exploded, methane is not easy to burn efficiently and the flame temperature is very low because of the large volume of air needed, so that bunsen burners and domestic cookers or heaters designed for coal gas cannot be easily adjusted to burn the gas from sewage sludge digesters.

Surface combustion devices in which the flame impinges on a heated active surface as e.g., of firebrick, are most effective for achieving high temperatures with methane.

In several towns in Germany since about 1930 sewage sludge digester gas has been mixed with coal gas and distributed in the

town gas mains, and sludge gas is being used in many towns in gas engines for production of power. Johannesburg has gas engines totalling some 850 H.P. at three of its sewage works.

Natural gas and sludge digester gas have been compressed, carried in cylinders and used as substitutes for petrol in motor vehicles.

This use of compressed sludge digester gas was demonstrated in Johannesburg in 1934 when the City Engineer's Department hired a compressor and the light steel cylinders, etc., to equip a 3-ton lorry which was operated for some six months on gas from the Cydna Sewage Works, Johannesburg.

Details of this demonstration were given in a paper by Mr. J. J. Pollock, M.Sc., read before the South African Institute of Engineers in 1935. It will suffice to say that the demonstration was quite successful and that the lorry had a range of nearly 100 miles when the cylinders were charged to 3,000 lbs. per square inch pressure.

Suggestions have been made that liquid methane carried in steel vacuum jacketed vessels could be used as motor fuel. There is, of course, nothing impossible in this suggestion, but the safety of liquid gas carried in insulated low pressure containers has not yet been demonstrated as fully as the safety of the thin chrome-molybdenum-steel cylinders has been, by exhaustive tests.

2. *Use of Methane for Production of Carbon Black.*

Some 12 per cent. of the enormous volume of natural gas collected in U.S.A. is used to produce Carbon or Methane Black. The process consists in merely burning the natural gas in burners designed to give a smoky flame and in allowing the smoke to impinge on some solid surface. Although methane normally burns with a pale almost invisible flame, by suitable pre-heating of air or gas, or both, pyrolysis of some of the methane can be achieved with production of carbon which may be collected on a cooled surface.

3. *Use in Metallurgical Processes.*

Natural gas has been found useful in the production and treatment of special steels in which a carefully adjusted carbon content is necessary. By using methane hydrogen mixtures in adjusted proportion a " neutral " atmosphere which will neither add to nor remove carbon can be obtained.

The very brief summary I have just given of the uses to which methane has already been put on a large scale must suffice for this address, because I wish to direct your attention to potential uses; but before doing so, it will be useful to mention a few outstanding chemical and physical properties of methane.

Pure methane is a colourless gas without odour, it is lighter than air being of specific gravity 0·55, when air = 1. It is almost insoluble in water and is only slightly soluble in organic liquids at ordinary pressures.

At 0°C and 140 atmospheres pressure methane liquefies, liquid methane boils under the ordinary atmospheric pressure at −165°C and solidifies at −184°C.

Methane burns in air with a very pale almost invisible flame. In a concentration of 5 per cent. in air it can easily be ignited with explosion.

Much work, in connection with air in coal mines, has been done on the detonation of methane—air mixtures, and it may be noted that the explosion wave in such a mixture may travel with a velocity of over 2,300 metres per second.

Chemically, methane is very stable as its symmetrical formula would suggest. It is unaffected by strong acids, but reacts readily with the halogens, in fact mixtures of methane with chlorine react with explosion when exposed to light.

Methane is very stable towards heat and it may be regarded as the ultimate hydrocarbon to survive in high temperature processes involving carbonaceous materials in the range 500° to 1,500°C.

The stability of methane towards heat and most chemical reagents has been the obstacle to its use in chemical processes, but since great stability of a molecule signifies well balanced and powerful atomic forces holding the molecule together, it follows that when means for disrupting the molecule by throwing the internal forces out of balance can be found, the very forces which were responsible for stability will render the disrupted molecule intensively reactive for other chemical combinations. In other words once we have learned the trick of making a very stable molecule unstable, we have at our disposal a powerful synthetic agent.

Methane in Chemical Synthesis.

A large number of attempts have been made to utilise methane in chemical production processes, and although, so far, these attempts have on the whole not been commercially successful, so much has been learned from repeated failures or limited successes that there is now reason to expect that methane will eventually prove to be one of our most important raw materials for a diversity of synthetic processes.

Pyrolysis of Methane.

A very large amount of work has already been done towards the direct and catalytic decomposition of methane by heat.

Outstanding workers in this field have been Bone, Wheeler and Coward in Great Britain, Fischer and Tropsch in Germany, and Egloff and Frolich in U.S.A.

From the great mass of published data I can only give here a brief summary:—

On heating, methane is stable up to some 500°C. Thermodynamic calculations indicate the decomposition into carbon and hydrogen should be nearly complete at 700°C, but actually equilibria are reached between methane and its decomposition

products in varying proportion according to the temperature maintained, so that even after several hours' heating at 785°C, 91·6 per cent. of the methane remained undecomposed. Between 1,100° and 1,200°C the methane remaining is of the order of 10 per cent.

Surface catalysis by walls of the containing vessel or heating surface may facilitate decomposition at lower temperatures, and a very large amount of careful work has been done on controlled, catalysed, or induced pyrolysis of methane.

The chemistry of the transformations which take place on pyrolysis of methane cannot be extensively discussed here. The equation $2\ CH_4 \rightleftharpoons C_2 + 2H_2$ only represents the extremes of a series of reactions.

It is believed that hydrogen is split off in stages thus, $CH_4 \rightleftharpoons CH_3 + H$ giving the free radicle methyl and atomic hydrogen. The free methyl radicle may almost immediately combine with itself to give ethane C_2H_6 and the hydrogen atoms may combine to give molecular hydrogen, but in presence of dissociating methane and also free methylene radicles produced by splitting of two hydrogen atoms (thus $CH_4 \rightleftharpoons CH_2 + 2H$) a very complex system must be present including atomic hydrogen and active carbon surfaces, so that a whole series of new combinations may be expected and indeed actually take place.

What the end products may be will depend largely on the conditions maintained. As an example of the effect of limiting conditions it may be mentioned that from 500°-1,200°C only methane and acetylene of all hydrocarbons can survive whilst above 1,200°C acetylene only can survive.

A considerable amount of work has already been done and published on the detailed study of conditions which give rise to useful products and I will briefly refer to some of the most interesting of the products obtained.

Production of Ethylene and Acetylene, by pyrolysis of methane has been studied and the yields determined in varied conditions of working.

It appears that when the combined partial pressures of ethylene and acetylene reach a maximum value which depends also on the pressure of the methane, further production of ethylene and acetylene ceases.

Production of Benzene, though the amount produced on pyrolysis of methane is small, the conversion is efficient. If some cheap and easy method of separating the hydrogen produced from the unaltered methane could be found, recirculation methods would perhaps result in a practical process for production of benzene, and other aromatics from methane.

So far as I can discover, there has not been any published information that the production of ethylene, acetylene or benzene from methane or natural gas has yet been developed on large scale.

Induced Pyrolysis of Methane.

By the addition of small quantities of other substances as inductors it has been found that the pyrolysis of methane can be effected at temperatures much lower than required for methane alone.

As inductors, halogens, halogen derivatives, sulphur compounds, oxides of nitrogen and other hydrocarbons have been found effective.

Because of the presence of other hydrocarbons with the methane it is found that the methane of natural gas will decompose under conditions in which methane alone will not break up.

Production of Carbon Disulphide.

From methane and sulphur vapour over silica gel catalyst at 550°-600°C, carbon disulphide may be produced.

Chlorinated Methanes.

As has already been mentioned, chlorine and methane react with explosive violence if the mixture made in the dark is exposed to bright light.

By taking careful precautions involving step by step additions of small quantities of chlorine to excess of methane and use of catalytic surfaces kept a suitable temperature the chlorination of methane may be achieved without danger.

All four chlorinated methanes, Methyl Chloride, Methylene dichloride, Trichloromethane or Chloroform and Carbon tetrachloride may be produced.

Methyl Chloride is a most important refrigerant as well as a fumigant. Methylene Chloride is a useful synthetic agent.

Chloroform and carbon tetrachloride are immensely useful solvents whilst carbon tetrachloride is used in the pyrene type of fire extinguisher.

Mixed chlorinated and fluorinated methane is used in refrigeration in the form of Freon type of products.

Nitromethane may be produced by the direct union of methane and nitric acid by passing carbon dioxide through nitric acid of 67 per cent. (constant boiling) concentration and the mixture steam, carbon dioxide and nitric acid is passed into the stream of methane.

The nitro-paraffins are synthetic agents of immense importance so widely useful that they have been compared with nitrobenzene.

The use of nitromethane has not been developed because until recently large scale production of nitromethane was not possible.

New chapters in synthetic chemistry will be opened up especially in the production of nitro-compounds, amino-com-

pounds, diazo-compounds, hydroxylamines, nitro-alcohols and amino-alcohols, when the production of nitromethane is developed on large scale.

Partial Controlled Oxidation of Methane.

The idea of partially oxidising methane to give formaldehyde by the reaction $CH_4 + O_2 = CHOH + H_2O$ is a very attractive one, but it has proved a very elusive one. A very large amount of work has been done in several countries since about 1915 and many patents have been taken out for the limited oxidation of methane to formaldehyde.

Ozonisation of methane was a method persistently favoured and another method frequently discussed and attempted was oxidation by the aid of nitrogen trioxide in air mixture.

Early in this war when shortage of formaldehyde became acute in South Africa, the staff of the Laboratory Division of the Johannesburg Public Health Department, of which staff I have the honour to be leader, devoted much time to attempts to produce formaldehyde by the ozonisation of methane.

The yields were only of the order of milligrams of formaldehyde per litre of methane, and as had previously been shown by the late Sir G. T. Morgan's team at the British D.S.I.R. Laboratories, such minute yields cannot economically be recovered and concentrated.

Splitting the Methane Molecule by Electrical Means.

Pyrolytic methods of splitting the molecule suffer from the difficulty that only methane is stable from about 500° to 1,200°C. so that having cracked the molecule it is necessary to instantly cool the products of reaction before the reverse action or polymeric actions can occur.

On the other hand if the temperature is carried up much above 1,200°C only acetylene can survive.

The flame arc and the electric spark present means whereby gaseous molecules may be subjected to sudden intense heat and disruption, and also allows rapid cooling of the gas stream to be carried out.

After the disappointing results of attempts to produce formaldehyde by limited oxidation of methane, the staff of the Johannesburg Municipal Laboratory Division began work on the splitting of methane in the electric arc and spark.

By means of a high tension electric spark, between water cooled metal points, blown out into a long flame by a rapid stream of methane at low pressure, it was found that the methane could, with quite reasonable efficiency, be broken up into acetylene and hydrogen.

This reaction has been studied by others and the power requirements are slightly less than is required to produce calcium carbide for production of equivalent acetylene.

The problem of separation of the large amount of hydrogen from the acetylene was not solved by us, but the use of the acetylene hydrogen mixture was carried on laboratory scale as far as production of acetic acid by methods already developed on large scale elsewhere.

We were beginning to prepare designs for the components of a pilot plant for production of acetylene and further products from acetylene, when it was suggested to us by the Wartime Research Committee that we should again devote attention to the production of formaldehyde.

The Methanol Condensation.

As an alternative to ozonisation directly to formaldehyde we had considered the high pressure condensation of $CO + 2H_2$ to Methyl Alcohol and made a study of the catalytic dehydrogenation of Methyl Alcohol to formaldehyde.

On laboratory scale we had already demonstrated in 1941 that the correct $CO + 2H_2$ mixture could be obtained by subjecting sewage sludge digester gas of about 70 per cent. methane 30 per cent. carbon dioxide with added water vapour, to a nickel catalyst on fireclay at about 900°C.

I cannot attempt here to tell you the whole story of this synthesis, in fact, the story is to be continued as somewhat of a serial. Great difficulties were encountered in getting suitable materials to construct a pilot plant which was designed to handle the output of the only high pressure compressor available in the country—the compressor already spoken of in the demonstrations of the use of compressed sludge gas to drive a 3-ton lorry in Johannesburg in 1934.

Messrs. J. A. McLachlan and A. H. Meyling carried through the laboratory and pilot plant trials and research, assisted later by Captain J. R. Gaillard, S.A.E.C., also of our laboratory division staff, but loaned back to us from Military Service with the 23rd Anti-Gas Laboratory, by the kind influence of Dr. de Villiers, Technical Adviser to the Department of Commerce and Industries.

Throughout the design, construction, and operation of the pilot plant we were helped by the staff of the Johannesburg City Engineer's Department, especially by Mr. Pybus and Mr. Jeffrey.

It was not until the end of 1943 that we were officially asked by the Department of Commerce and Industries to develop the pilot plant and difficulty in getting components to stand the severe furnace conditions at 900°C delayed development, but I am glad to be able to record that the difficulties and teething troubles of the pilot plant were so far overcome that we got the first small output of Methyl Alcohol at the end of March, 1945.

Details of the work will be published later by Messrs. McLachlan, Meyling and Gaillard when this and other high pressure reactions have been further studied on the pilot plant.

Modification of the Methanol Condensation.

Quite an extensive amount of work has already been done on the production of hydrocarbons, alcohols, aldehydes and other compounds from mixtures of carbon monoxide and hydrogen.

The reaction $CO + 2H_2 = CH_3 OH$ may be modified by the use of specially selected catalysts and by varying the temperature and also the proportions of carbon monoxide and hydrogen.

Orloff (J. Russ. Phys. Chem. 1908-40-1588) as early as 1908, observed that when carbon monoxide was reduced by hydrogen at 100°C in presence of a nickel-palladium catalyst mounted on asbestos, unsaturated hydrocarbons were formed.

In 1913, the Badische Anilin und Soda Fabrik took out D.R.P. 20481 of 1913. Many workers of whom Patart (France), Fischer and Tropsch (Germany), Egloff (U.S.A.) and Morgan (England), are perhaps the best known in this field, have since added to the published information.

Fischer and Tropsch used alkalised iron catalyst to reduce carbon monoxide with hydrogen and obtained a liquid (chiefly hydrocarbon) mixture known as synthol. Using a pure metal catalyst they produced at low pressure and low temperature (200°C to 300°C) a mixture of liquid hydrocarbons almost free from oxygenated compounds.

It is clear that by using a catalyst impregnated with alkali metal the menthanol condensation is directed towards the production of higher alcohols than methanol.

Thus in one experiment by Morgan, Hardy and Proctor, (J.S.C.I., T. 1. 1932) in which a chromium manganese catalyst containing up to 15 per cent. rubidium was used, the distribution of carbon in the liquid products was, in methanol 42 per cent., in other alcohols 38 per cent., in aldehydes, acetals and acetones 15 per cent., in acids less than 1 per cent., whilst in the gas there was 2 per cent. methane, and 2 per cent. carbon dioxide, indicating a very efficient process.

The following products were indentified, alcohols—methyl, ethyl (trace only) propyl, isopropyl, iso butyl, B methyl butanol, B methyl pentanol, B.d iso dimethyl pentanol: aldehydes—formaldehyde, propaldehyde, hydroxyaldehydes and other higher aldehydes.

This synthetic mechanism of modified methanol condensation has hardly yet been explored, but already it is certain that by modifying the gaseous mixture, the catalyst, the temperature and the pressure, the desired products may be increased.

Hydrogen Cyanide.

By the interaction of methane and ammonia and air at temperatures between 1350° and 1450°C hydrocyanic acid is

produced. Catalysts for producing HCN at lower temperatures have been the subject for patents.

In 1931 (Brenstoff Chemie 1931-12-122) it was shown by Peters and Keisch that by passing an electric discharge through a mixture I:I of methane and ammonia at low pressure, hydrogen cyanide may be produced.

The production of cyanide is, of course, of special interest to the Witwatersrand and experiments are being made on small pilot plant scale for the production of HCN, but so far I have not received any information or data that I can put before you.

From observations made on the pilot plant at the Cydna Laboratory, there seems a possibility that other nitrogen containing compounds may be producible by modifications of the methanol condensation.

Photochemical Decomposition of Methane.

Although hardly explored as yet it is of great interest to note that by the action of the radiation of the mercury vapour arc lamp on methane in presence of a trace of mercury vapour, ethylene, ethane and hydrogen as well as higher saturated and unsaturated hydrocarbons are formed.

Nitromethane is also photochemically decomposed in similar conditions to give aldehydes and hydroxylamine.

Wartime Progress.

Very great progress has been made, especially in U.S.A., in the controlled pyrolysis of petroleum hydrocarbons, and although we shall have to wait until the end of the war in the Far East for any adequate information occasional scraps of news have filtered through censorships which have hinted at great developments in the use of methane mixtures in synthetic processes.

The wide variety of applications of methane to which I have briefly referred should suffice to make it plain that in methane we have not merely an inflammable gas so inert and stable, that it can only be used as a fuel but rather a raw material that may constitute a basis on which to found an important chemical industry.

Olefines, acetylenes, higher alcohols, aldehydes, ketones, nitromethane and amino compounds suggest a very attractive picture to the organic chemist but the efficient production of these possibilities can only be achieved after further careful laboratory and pilot plant research and even then the industrial uses of the products will still have to be developed.

There are, however, practically no uncertainties about the uses to which the halogenated methanes, cyanides and formaldehyde may be put.

I should like to draw your serious attention to the immense importance of formaldehyde which has already become one of the

key substances—almost *the* key substance for the future development of the plastic industry, because important developments in South Africa might hinge on the establishment of a plastics industry here.

I need not try to tell you of the great development of the plastics industry elsewhere. Small moulded articles in ever increasing variety and number have been familiar to us for years. Larger moulded articles were appearing just before war began, but during the war immense advances have been made. By impregnating soft woods or other fibrous materials with suitable plastics, moulded, cemented, or built up articles of great size and strength may be produced.

Soft woods impregnated with plastic have become a material of construction superior to hard woods, and capable of replacing metals for many purposes.

Now the South African Forestry Department has shown that in some districts in South Africa some soft wood trees grow with phenomenal rapidity and recently Dr. H. H. Bennet of U.S.A., when asked if he could suggest any product which South Africa could grow better than any other country, expressed the belief that in production of soft woods this country might lead the world.

Soft wood production alone may not seem a very satisfactory aim, but with the simultaneous development of a plastics industry, impregnated soft woods and other quick growing fibrous materials could become a major export industry, which could be in full scale output within twenty years.

As this suggestion implies possible solution either wholly or in part of some of our most pressing national difficulties—soil erosion prevention, soil conservation, restitution of soil fertility—redistribution of labour, and contribution to our own and other countries housing and related problems, it is hardly possible to exaggerate its importance.

I cannot go into further details here, but wish to stress that formaldehyde is a key material for production of many synthetic chemicals, but it also may be a product of vital importance to the future of South Africa.

It is perhaps necessary that I should add that as formaldehyde is obtained by the dehydrogenation of methyl alcohol which is being made on very large scale overseas from water gas by the methanol condensation, the establishment of a plastics industry based on formaldehyde does not depend on the methane supplies available, though if large supplies of methane are available methyl alcohol and formaldehyde may be produced from this source as we have shown on the pilot plant at the Johannesburg Municipal Laboratory.

This brings me to the question as to what methane is available in this country.

Methane in South Africa.

Enquiries made at the Mineral Research Laboratory, Witwatersrand University, the Geological Survey and the Fuel Research Institute yielded no information except one or two analyses of natural gas.

The Officer in Charge of Mineral Development, Department of Mines, informed me that in 1926, a company called the Devon Petroleum Prospecting Syndicate, Ltd., was floated for the purpose of exploiting the (methane containing) gas which had been issuing from a borehole on the farm Gruisfontein, No. 48, District Heidelberg, Transvaal. It was considered, on what grounds I am not clear, that the gas had originated from paraffin oil.

Three boreholes put down at selected points near the gas well yielded no gas, but the failure appears to have been due to the presence of two or more dykes of intrusive dolerite which had sealed off the gas from lateral travel.

At 1,074 feet drilling was stopped and the whole prospect abandoned, although the Minerals Department Officer would have liked to continue the work.

The search for natural gas ought clearly to be a national matter, and it is likely that careful study and selection of drilling sites would result in extensive supplies of natural gas from the South African coal measures.

No official information was available concerning the amount of the gases, but after private inquiry I learned that in the case of the borehole just referred to measurement revealed that about 20,000 cubic feet of gas per day was issuing. Since this borehole has been blowing for over twenty years it is possible that from this one borehole there has been wasted over a hundred million cubic feet of gas.

Our coalfields in South Africa are of great extent and it is at least likely that there are large amounts of natural gas somewhere. Just where the gas has been trapped and where to put down the recovery boreholes requires investigation.

T. N. Dewar, J. Chem. Met. and Min. Society, 1921, page 130, estimated that gas containing methane which had caused an explosion was "making" in pockets in the No. 1 shaft section of Daggafontein Gold Mine at the rate of 190 cubic feet per minute which works out at over a quarter of a million feet per day. In this case the gas had travelled down from overlying or adjacent coal measures.

Experts in Oils and Natural Gas will be able from geological data to advise where boreholes may be expected to yield useful amounts of gas.

Investigation of the possible recovery of natural gas is worthy of a national survey, and well justifies the cost of expert advice and the necessary plant, boreholes and pipe work.

If on careful investigation it is proved that there are in the Union large supplies of natural gases containing methane and other hydrocarbons, then the establishment of a large chemical industry using the natural gas as raw material at once becomes a possibility and just which products should first be made should receive concentrated study.

If on the other hand the natural gas recoverable turns out to be insignificant in amount then the small amounts available at the various sewage disposal works become at once of great importance, and whilst the planning of industry based on methane must be on smaller scale it is essential that the small amounts available should be put to the wisest possible use for the country's need.

As I stated at the beginning, this address is intended to focus your attention, as a group of scientists who have a very wide field of knowledge and activity, on the possibilities of methane.

The problems involve several branches of science and clearly a group such as Section B of this Association could supply the breadth of outlook necessary to cope with the problems involved.

I suggest to you that the investigation of the country's resources in regard to natural gas and other sources of methane or other hydrocarbon gases, and the development of industry planned in accordance with the magnitude of the sources revealed in the investigation, is a task worthy of the serious co-ordinated efforts of Geologists, Mining and Petroleum specialists, Chemists, Chemical Engineers, Physicists and Biologists and as the S.A.A.A.S. is the meeting ground of workers in all these fields, I suggest that S.A.A.A.S. might give a lead to the whole country in the investigation and development of the asset.

I need not here try to detail the kind of organisation required, obviously field investigation by geologists and specialists in natural gas and oil will be needed, first to assess the natural resources and to tap them. A research station equipped for pilot plant scale investigation of high pressure and high temperature reactions is the next requirement.

The most essential items of equipment for such a laboratory are already in existence at the Johannesburg City Council's Cydna Laboratory where they were provided by the City Council as a contribution to the nation's war effort, for the production of formaldehyde.

As prolonged fundamental research into the whole field of high pressure and high temperature reactions is rather a national than a municipal matter, I suggest that the equipment at Johannesburg might be acquired by a national research group and that with a minimum of delay the staff to continue work on this pilot plant should be provided.

I would finally add that in this country we have also men who are capable of planning, directing and doing the work, it remains for the sanction and the necessary funds to be provided in the certainty that the nation will gain, perhaps on a very large scale.

I should like to record my appreciation of the policy of the Johannesburg City Engineer, and the Medical Officer of Health in recommending to the City Council that the pilot plant should be provided at the Cydna Laboratory, and my thanks to Dr. de Villiers and the Department of Commerce and Industries for facilities and help.

SUMMARY: The occurrence of methane in natural gas in enormous volumes in several countries, in association with oil or coal is mentioned.

Although in the past natural gas was largely wasted the amounts used are now immense, especially in North America.

Sewage sludge digester gas contains methane and it is also possible that methane could be produced on large-scale by the action of nitro-organisms on waste vegetable matter.

The large-scale uses to which methane and natural gas have already been put are briefly mentioned.

Some of the products which may be made from methane by pyrolysis and catalysed or induced pyrolysis are discussed.

The very wide variety of chemical products which may be obtained by various processes from methane suggests that new chapters in chemical synthesis may be opened up by large-scale exploitation of these processes.

The methanol condensation and some of its modifications are discussed briefly.

Sludge digester gas with added steam has been converted to the correct mixture of $CO+2H_2$ and condensed to methyl alcohol CH_3OH in the Johannesburg Municipal Laboratory as a wartime effort on pilot plant stage.

Formaldehyde, which is a key substance for the establishment of a plastics industry, can be made from methane if there are adequate amounts of the gas available.

The resources of this country of natural gas containing methane have not been properly investigated, and it is urged that the exploration of this country's resources in natural gas is a matter for serious co-ordinated national effort by a group of scientists and technologists of wide scope, and that a high pressure and high temperature research station for further study of the uses of methane should be established as a national measure.

South African Journal of Science, *Vol. XLII, pp. 43-61, June, 1946.*

OECOLOGIA SUBTERRANEA: DIE GROND AS OMGEWING

DEUR

Professor W. J. Lütjeharms,

Afdeling Plantkunde, Universiteitskollege van die O.V.S., Bloemfontein.

Presidentsrede aan Afdeling C van die Suid-Afrikaanse Genootskap vir die Bevordering van Wetenskap, gelees 4 Julie, 1945.

Die veelsydige chemikus en politikus Johann Joachim Beccher het in 1669 in sy merkwaardige boek ,, Physica Subterranea " 'n saamvatting van sy vernaamste ideë op die gebied van die chemie en ook van die plante- en dierefisiologie gegee. Sy opvattinge was van groot invloed op Stahl se latere teorie van die phlogiston, wat die skeidkunde van die hele agtiende eeu sou beheers, totdat onder die invloed van Lavoisier die basis van die moderne chemiese begrippe gelê is. Behalwe dit, vind ons in Beccher se werk ook 'n uitvoerige, hoewel grotendeels spekulatiewe, uiteensetting van wat gebeur by die afbraak van dierlike en plantaardige stowwe, in die grond sowel as daarbuite. Die begrip van die kringloop, wat nog altyd so'n belangrike plek inneem in die mikrobiologie en in die ekologie, is in sy werk in beginsel aangedui. Hoewel die meeste van Beccher se opvattinge tans alleen nog maar historiese waarde besit, het ek die titel van my onderwerp gekies na analogie van Beccher se ,, Ondergrondse Fisika." Laat my toe om u te verseker dat die ,, oecologia subterranea " geen nuwe ondergrondse beweging is nie, en dat—hoewel die ondersoek van die grond as omgewing vir lewende organismes heel wat ondergrondse werk meebring—dit 'n saak is wat die daglig in alle opsigte kan verdra.

Ontwikkeling van die Bodem-Mikrobiologie

Die grondwetenskap in die algemeen en die grond-mikrobiologie in die besonder, het ontwikkel as dele van die landbouwetenskap, d.w.s., van 'n wetenskap met 'n doelstelling wat in die allereerste plek prakties is. Die ondersoek van gronde, in die begin vernaamlik met chemiese metodes, het as hoofdoel gehad die verbetering van die grondvrugbaarheid, die bevordering van plantegroei en die vermeerdering van opbrengs. Vanaf die begin was dit duidelik dat die grond 'n uiters gekompliseerde geheel vorm, wat nie homogeen van samestelling is nie, maar van plek tot plek variëer, ook daar waar op die grondkaart slegs een kleur of arsering voorkom. Daar is dan ook reeds vroeg in die moderne

grondskeikunde aandag geskenk aan die metode en tegniek van monstername: om die juiste behandeling (met kunsmis of wat ook al) per eenheid van grond vas te stel moet 'n verteenwoordigende aantal monsters geneem en geanaliseer word. Vir praktiese doeleindes word die monsters gemeng en daarna herhaaldelik verdeel, totdat 'n gemengde monster van voldoende grootte en hanteerbaarheid verkry is. Hierdie saamgestelde monster moet buitendien voldoende vertoonwoordigend wees. In veldproewe moet vir 'n toevallige verspreiding van die proefakkers gesorg word. Die statistiese bewerking van die resultate wat met hierdie metodes verkry is, het baie aandag geniet: dit is van groot belang omdat dit die basis van die betroubaarheid van die analitiese werk vorm. Die uiteindelike resultaat kan dan feitelik beskou word as die gemiddelde van 'n groot aantal individuele waarneminge, gedoen op 'n gebied met 'n groot variasie, naamlik die grond.

Die toepasbaarheid van dergelike deursneewaardes vir die behandeling van die grond is deur die praktyk voldoende aangetoon. In baie gevalle kan hierdie gegewens ook gebruik word vir vergelykingsdoeleindes. Dit is ook moontlik om uit soortgelyke eksperimente gevolgtrekkinge te maak wat van meer algemene strekking is en die grondslag kan vorm vir die algemene beginsels en wette waarmee die pedologie die veelheid van verskynsels op sy gebied kan rangskik en verklaar. Sonder oordrywing kan gesê word dat die grondwetenskap, altans die ouere, grotendeels op hierdie wyse opgebou is.

Ook in die grond-mikrobiologie, wat sy ontwikkeling feitelik in die landbouskeikundige laboratoria begin het, is die metodes oorspronklik opgebou op die beginsel van ondersoek van groot gebiede. Die eerste vrugbare metode wat hier ontstaan het, was die plaatmetode. Die monsters word steriel geneem en verder onder steriele omstandighede behandel op die selfde manier as vir chemiese ondersoek. 'n Steriele suspensie word sonder of na besinking in verskillende verdunninge uitgesaai op agar- of ander plate. Die beginsel van elektiewe kultuur, waarby verskillende voedingsbodems gebruik word om verskillende groepe van mikro-organismes te laat ontwikkel, is reeds by die eerste begin van die bodem-mikrobiologie onder Beijerinck en Winogradsky ingevoer en is later uitgebrei en vir kwantitatiewe doeleindes aangepas. Met hierdie metode was dit moontlik om gegewens te kry oor die aantalle mikro-organismes van verskillende groepe (fungi , actinomycetes, fisiologiese bakteriegroepe, protozoa, algae) wat in verskillende grondtipes voorkom, by verskillende behandeling, op verskillende tye van die jaar, ens. Maar ook het op die manier die kwalitatiewe studie van die mikrobes moontlik geword: die gevolg was 'n intensiewe ondersoek na die grondflora in verskillende lande van die wêreld. Nog altyd word hierdie metode toegepas: nog altyd word nuwe organismes beskryf wat vantevore nie in die grond aangetref was

nie, of wat heeltemal nuwe vorme voorstel. Vir die sistematikus-mikrobioloog en- bakterioloog is en bly die grond 'n amper onuitputlike bron van materiaal. Die feit dat 'n aantal groepe van organismes, soos b.v., die basidiomycetes, nie of moelik met die plaatmetode kan geisoleer word nie, moet altyd in gedagte gehou word maar dit doen aan die algemene bruikbaarheid van die plaatmetode vir vergelykingsdoeleindes niks af nie.

Soos vanself spreek is die groot vraag vir die bodem-bioloog nie in die eerste plek watter organismes in die grond voorkom nie, maar wat hulle daar doen, wat hulle werksaamheid is. Hierdie vraag kan nie so direk beantwoord word nie. Reeds by die toepassing van die elektriewe kultuurmetodes is die organismes verdeel in fisiologiese groepe wat betref hulle voorkeur vir 'n sekere (kunsmatige) omgewing, n.l., ten opsigte van aard van voedsel, suurstofvoorsiening, reaksie van die milieu, ens. Hierdie gegewens is uitgebrei met 'n meer gedetailleerde fisiologiese ondersoek van die betreffendeorganismes, met die gevolg dat 'n uitgebreide literatuur op fisiologiese gebied ontstaan het.

Naas die oorsig van die vorme en hul kwantitatiewe voorkoms op grotere proefakkers, soos dit deur die plaatmetode gegee word, het ons deur hierdie fisiologiese ondersoek 'n denkbeeld gekry van wat daar, dinamies, in die grond mag aangaan. Ons moet hierdie „ mag " beklemtoon, want dit kan nie ontken word dat daar in baie gevalle slegs 'n „ Hineininterpretierung " plaas gevind het nie. Vir 'n volledige kennis van wat werklik in die grond gebeur, vir die ontwerp van 'n dinamiese beeld van die aktiwiteite van die grond-organismes is dit alles egter onvoldoende.

Ekologiesie Gesigspunte

Om hierdie gevraagde dinamiese beeld van die mikrobiale werksaamheid in die grond te ontwerp, is meer nodig as net die sistematiese of floristiese kennis van die organismes self, of die kennis van hulle fisiologiese bedrywighede of potensies. Ons kom hierby geheel op ekologiese gebied, in die eerste plek omdat ons hier te doen het met die organismes in hulle natuurlike omgewing. Maar, soos Bews in sy Voorsittersrede vir hierdie Genootskap in 1931 op so voortreflike wyse uiteengesit het, is die ekologie minder 'n spesifieke onderdeel van die biologiese natuurwetenskappe, as wel 'n uitkyk, 'n geesteshouding, wat naamlik die lewe op 'n bepaalde gebied as 'n geheel probeer beskou. Dan word die ekologiese beskouwing van bepaalde biologiese probleme die sintese van alles wat op hierdie gebied bekend is. In ons spesifieke geval sal ons behalwe die floristiek en die verspreiding van die bodem-organismes, ook hulle biochemie, fisiologie onderlinge verhoudinge en nie die minste hulle gekompliseerde woongebied, naamlik die grond self, moet beskou.

Maar ons moet erken dat die ekologie van die mikro-organismes 'n gebied is met nog meer vraagtekens as die tog reeds ryklik hiermee bedeelde gebied van die ekologie van die hoër plante. Die natuurlike omgewing, die **οἶκος** van hierdie

mikro-organismes is die grond. Maar dit is nie net hulle milieu nie, hulle moet dit deel met 'n menigte van ander organismes, met diere van die mees verskillende groepe, as ook met die ondergrondse dele van plante. So word daar dus 'n biocoenose van buitengewone ingewikkeldheid gevorm. Dit is my bedoeling om 'n paar van die mees opvallende en belangwekkende punte hiervan nader te bespreek. Dit is egter onmoontlik om volledig te wees en ek sal dan ook geen poging daartoe doen nie.

Die grondslag van elke ekologiese studie moet die autekologie wees, die studie van die gedrag van die afsonderlike soort (of variëteit, of ander elementêre sistematiese eenheid) ten opsigte van sy omgewingsfaktore. Die basis van die autekologie van die mikro-organismes is deur Beijerinck gelê in 'n hele reeks van ondersoekinge. Alle fisiologiese werk oor mikro-organismes, in die besonder sover dit die studies oor voeding, reaksie op die omgewingsfaktore, ens., betref, kan tot 'n nadere kennis van hulle autekologie bydra. Dit is op die gebied van die mikrobiologie nog moeiliker as by hoër plante om die skeidslyn tussen fisiologie en autekologie vas te stel, wanneer daar altans so iets bestaan en die grenslyn nie eerder denkbeeldig of kunsmatig is nie.

Hierdie fisiologiese autekologie van die mikrobes is reeds op allerlei maniere en by 'n groot aantal organismes bestudeer, maar tog het ons hierby, ondanks alle bereikte resultate, nog nie ver genoeg gekom nie. Die natuurlike omgewing waarin 'n organisme voorkom, kan vir analitiese doeleindes teruggebring word tot 'n aantal faktore, maar by kultuur in die laboratorium blyk dat die totale gebied van faktore, waarby die organisme kan bestaan, baie wyer is as die faktorekompleks van die natuurlike omgewing. So kan ons onderskeid maak tussen die aktuele, werklike milieu en die potensiële milieu. Op dieselfde wyse kan ons in die laboratorium in reinkultuur-eksperimente, sowel as met sekere gemengde kulture, 'n hele reeks van fisiologiese potensies vir elke mikrobesoort vasstel. Maar hierdie eksperimentele omstandighede is in baie opsigte optimale toestande, wat in die natuur feitlik nooit of amper nooit verwesenlik word nie. So vertoon die studie van die grond as natuurlike, aktuele omgewing nog 'n groot agterstand. Dit is volkome begryplik wanneer op die spesiale moeilikhede van die ondersoek gelet word. Ons kan die natuurlike omgewing van die grond-mikrobes nie bestudeer nie, sonder om tegelykertyd daarin in te gryp en dit dus te verander nie. Waar die mikrobioloog ook al die natuurlike gedrag van die bacteria of fungi in die grond wil waarneem, daar moet hy veranderinge in die natuurlike milieu aanbring en die werksaamheid van die mikrobes stimuleer, omdat die suiwer observasionele metode wel belangrike, maar tog ook ontoereikende resultate oplewer.

Ewemin as tussen fisiologie en autekologie is daar 'n skerp skeiding moontlik tussen die aut- en synekologie van die mikro-organismes, behalwe in die laboratorium waar ons met reinkulture kan werk. In die natuur bestaan daar nie so iets soos reinkulture

nie, tensy op baie klein gebiede (Starkey) en onder heel besondere omstandighede. Soos ons nog sal sien het sekere aspekte van die synekologie van bodem-organismes in die laaste jare sterk op die voorgrond getree en aanleiding gegee tot praktiese resultate van besonder groot belang op sekere gebiede ook buitekant die grond-mikrobiologie.

Autochthone en Zymogene Flora.

In baie opsigte kan ons dus Beijerinck beskou as die grondlegger van die ekologie van die mikro-organismes. Daarnaas is Winogradsky die vader van die ekologie van die grond-mikrobes. Van 1924 af het Winogradsky begin wys op die ontoereikendheid van die toentertyd in die grond-mikrobiologie gebruiklike metodes. Die veral deur hom aanbevole metode van direkte waarneming sal ons later in ander verband bespreek. Hier wil ek net wys op 'n onderskeiding van verstrekkende betekenis wat aan sy werk te danke is, naamlik dié van autochthone en zymogene mikroflora. Hierdie onderskeiding is van groot teoretiese belang omdat in baie gevalle die grondpopulasie bestudeer word na behandeling van die grond, d.w.s. na toevoeging van bepaalde stowwe: organiese sowel as kunsmisstowwe. Die opvallende gevolg van 'n dergelike behandeling is 'n duidelike verandering van die mikropopulasie, nie alleen kwantitatief nie, maar ook kwalitatief. Hierdie verandering is tydelik en wel gewoonlik só dat ons 'n reeks op mekaar volgende consocies en (of) associes kry en daarna in meerdere of mindere mate 'n terugkeer tot die oorspronklike mikroflora, naamlik dan wanneer die werking van die toegevoegde stof opgehou het en weer 'n stabiele toestand bereik word. Die mikroflora van hierdie stabiele toestand bereik word. Die mikroflora van hierdie stabiele toestand noem ons die autochthone populasie, dié wat sy groot opbloei kry na toevoeging van bepaalde stowwe, noem ons die zymogene flora. Hoewel ons moet aanneem dat die kieme of diaspore van die zymogene flora ook reeds voor die ontwikkeling daarvan aanwesig was, en dat die zymogene flora ook in een of andere vorm bly voortbestaan nadat die toestand van stabiliteit weer herstel is, het dit duidelik geblyk dat daar gedurende die stabiele periode feitelik niks van die zymogene flora kan waargeneem word nie.

Hier kry ons een van die besware wat teen die plaatmetode kan ingebring word: vir 'n deeglike kennis van die autochthone flora moet 'n groot aantal verskillende voedingsbodems gebruik word en hierop sal ook dié organismes ontwikkel wat tot allerlei potensiële zymogene floras behoort. Vir die fungi is dit moontlik om onderskeid te maak tussen vorme wat as mycelium of as spore in die grond voorkom, nl. deur klein grondfragmente op plate uit te lé. Vir Bacteria en Actinomycetes bestaan daar dergelike differensiële metodes uit die aard van die saak nie. Ons wil hiermee nie beweer dat die plaatmetode onbruikbaar is om verskille tussen behandelde en onbehandelde monsters te demonstreer nie. Inteendeel, herhaaldelik is dergelike verskille

aangetoon en vir belangrike gevolgtrekkinge gebruik. Maar absolute verskille sal ons nooit op die manier kry nie.

Die „ stabiele toestand " waarna ons so-ewe verwys het, waarin dus die autochthone flora aanwesig is, is nie 'n toestand van volkome rus nie. Die autochthone flora besit die vermoë om die laere koolhidrate wat b.v. as gevolg van sellulose-afbraak in die grond gevorm word, te kan omsit onder prakties volledige verbranding tot CO_2, waardeur die ophoping van suiker belet word, sodat suurvormende bakterieë geen kans vir hulle werksaamheid kry nie (Conn). In 'n beperkte mate vertoon hierdie flora 'n konkurrensie vir stikstofhoudende verbindinge met die hoër plante, maar dit het eerder 'n gunstige as 'n ongunstige uitwerking op die laaste, deurdat by die vaslegging die nitrate vir uitloging bewaar word, en daar later dan 'n geleidelike mineralisasie van die stikstof kan optree. Behalwe bacteria (wat in die meeste gevalle die meerderheid vorm, met uitsondering b.v. van bosgronde of spesiaal sure en organiese gronde) behoort hiertoe ook 'n deel van die stadig werkende lignien-aantastende fungi, waarvan ons feitelik baie min weet.

Belangrike resultate is onlangs deur Newman en Norman (1942 en 1943) op hierdie gebied verkry toe hulle by verskillende grondsoorte die verandering van die grondpopulasie in horisonte van verskillende diepte ondersoek het. Nie alleen neem die grootte van die populasie af met toenemende diepte nie (dit was reeds eerder vasgestel en algemeen bekend), maar ook neem die potensies van die mikroflora af hoe dieper ons in die grond kom. Dit berus waarskynlik op die bestaan van 'n veel vastere verhouding as wat tot dusver aangeneem was, tussen die grondflora en sy direkte omgewing, in sover die laaste bepaal word deur die aard en hoeveelheid van die organiese materiaal en die fisiese omgewingsfaktore. Hier word die direkte afhanklikheid van die grondpopulasie van sy milieu beklemtoon en daardeur mag die moontlikhede van die zymogene flora op groter diepte baie meer beperk word as wat die oorspronklike ondersoekers op hierdie gebied gedink het. Dat die aanwesigheid van remmende stofwisselingsprodukte in diepere lae hierby 'n moontlike rol mag speel, doen aan die werklike stand van sake niks af nie. In dieselfde rigting wys ook die bevinding van Lochhead en Chase, dat die bakterieflora van vrugbare gronde gemiddeld hoëre voedingseise stel as dié van minder vrugbare gronde, m.a.w. dat die graad van heterotrofie in vrugbare gronde hoër is, aangesien hier baie bakterieë voorkom wat nie sonder spesifieke organiese voedingstowwe (aminosure b.v. of spesifieke groeifaktore, wat gedeeltelik van mikrobiale oorsprong is) kan klaar kom nie. Hoe ryker die omgewing, hoe gekompliseerder die beeld van die mikrobiale lewe!

Die Direkte Metodes.

Die plaatmetode gee vir ons 'n begrip van die kwalitatiewe en kwantitatiewe eienskappe van die bodemflora, maar dit gee geen opheldering omtrent die werklike aktiwiteit van sy kom-

ponente in die grond nie. Ook die inaktiewe russtadia van verskillende organismes kom op die plate tot ontwikkeling. Aan die ander kant kry ons deur die fisiologiese ondersoek van reinkulture 'n idee van die *moontlike* reaksies en aktiwiteite van die betreffende organismes in die grond. Hoewel albei metodes baie bygedra het tot die ontwikkeling van die grond-mikrobiologie en albei nog steeds onmisbare hulpmiddele vir die studie van die bodem-biologie vorm, was daar ander metodes nodig om die biologiese prosesse in die grond direk te kan bestudeer.

Die eerste, wat hiertoe oorgegaan het was Conn, wat in 1918 die s.g. direkte metode ingevoer het. Vanaf 1924 het Winogradsky die metode verder uitgewerk en toegepas. Albei ondersoekers maak gebruik van grondsuspensies in verdunde gelatien- of agaroplossinge, waardeur die grondkorrels en organismes op 'n voorwerpglas kan gefikseer word. Verder gebruik hulle sure kleurstowwe soos erythrosien en rose bengale, waardeur die organismes baie duidelik gekleur word in teenstelling tot ander organiese en kolloïdale stowwe in die grond. Die feit dat hier met grondsuspensies gewerk word, beteken weer dat die natuurlike toestand van die grond versteur word en dat die organismes nie in hulle direkte omgewing waargeneem word nie. Ek het egter gevind dat hierdie beswaar grotendeels kan opgehef word wanneer ons klein stukkies grond of plantedele (b.v. wortels of dooie reste) op 'n voorwerpglas in gelatienoplossing fyn maak en fikseer (gewysigde metode van Rossi). Meestal is dit dan moontlik om groter kwartskorrels, wat die waarneming onder sterke vergroting hinder, te verwyder. Hoewel hierdeur weer 'n deel van die grond van die waarneming uitsluit word, is dit nie so ernstig nie, omdat dit blyk dat op kleiner kwartskorrels, wat wel op hierdie manier kan waargeneem word, i.d.a. baie min of geen bakterieë gevind word nie. 'n Uitsondering moet gemaak word vir Fungi en Blouwiere wat in baie gevalle wel noue verbindings vorm met groter gronddeeltjies en daardeur in 'n groot mate bydra tot dat die stabiliteit van die boonste lae van sanderige gronde, soos ek dit in die Westelike O.V.S. herhaaldelik waargeneem het. Die waarneming van dergelike grotere organismes kan egter gerieflik by swakker of middelmatig sterke vergrotinge gedoen word. In die algemeen moet by die toepassing van hierdie metode rekening gehou word met die aard van die „ elementêre samestel " (in die sin van Kubiëna: Elementargefüge, elementary fabric) van die grond, d.w.s. die onderlinge rangskikking van die minerale deeltjies en die kolloïdale fraksie, en in verskillende gevalle moet op verskillende wyse gehandel word.

'n Verdere uitbreiding van die direkte metodes is die deur Rossi en Cholodny ingevoerde metode van begrawing van voorwerpglase vir 'n sekere tyd, waarna die op die glasies aanwesige organismes gefikseer en gekleur en dan verder bestudeer word. Dit is die tegniek wat feitlik die meeste gebruik word van alle direkte metodes, veral ook by die studie van die rhizosfeer, waarop ons later terug kom.

Nog verdere uitbreiding is later verkry deur toepassing van kweekmetodes met soveel moontlik ongesteurde grond, en wel op sodanige wyse dat die groei van die organismes direk mikroskopies kan waargeneem word. Veral Cholodny en Kubiëna het verskillende van dergelike kweekmetodes ontwerp en verdere waarneminge hiermee gedoen. In die algemeen kan op die manier meer bevredigende resultate bereik word vir die grotere Fungi en Actinomycetes as vir die bakterieë.

Deur die toepassing van hierdie direkte metodes het geblyk dat die bacteria en ander mikrobes nie homogeen in die grond versprei is nie, maar gelokaliseer is op die bepaalde plekke, vernaamlik daar waar organiese stof voorkom. Dit is wat a priori verwag kan word. Maar die metodes laat ook toe om onderskeid te maak tussen verskillende toestande waarin bakterieë in die grond voorkom. Meerdere ondersoekers, veral dié uit die skool van Giacomo Rossi (Portici) het gewys op die voorkoms van vliesvormige kolonies wat vernaamlik oor ontbindende organiese stof aangetref word en blykbaar 'n aktiewe vorm van bakterielewe in die grond voorstel.

In amper alle landbougronde (en in 'n mindere mate ook in natuurlike gronde) kom bakterieë voor in 'n karakteristieke vorm waarop Rossi wel as eerste die aandag gevestig het, nl. as „ glomeruli." Dit is meestal ronde, zoögloea-agtige versamelinge van kokkoïede bakterieë, wat deur duidelike slymagtige kapsels omgewe is. Dit is die mees voorkomende vorm waarin bakterieë by direkte waarneming in die grond aangetref word. In reinkultuur kom dergelike glomerulus-vorme baie min of selde voor. Hierdie glomeruli moet as rusvorme beskou word, en hulle word deur Rossi vergelyk met die cyste van Protozoa. In die grond is hulle vrywel onwerksaam, maar onder gunstige omstandighede sou daaruit aktiewe vorme kan ontwikkel, wat die oorsaak mag wees vir die dan optredende vinnige opbloei van die mikrobiale aktiwiteit. Ten opsigte van die feit dat hierdie glomeruli baie lank in grondmonsters waarneembaar bly (Rossi noem 'n tyd van 38 jaar) laat hulle dink aan die lang lewensduur wat wiere in die grond vertoon (Bristol-Roach).

Behalwe die algemeen verspreide glomeruli en die van tyd tot tyd voorkomende vliesvormige kolonies, vind ons bacteria ook in vrye toestand in die grond, maar slegs in uiters beperkte mate. Met die Rossi-Cholodny-tegniek is ook die studie van Actinomycetes en Hyphomycetes in die grond moontlik, wat by die oorspronklike metodes van Conn en Winogradsky groot moeilikhede gegee het.

Aan hierdie waarneminge wil ek nog toevoeg dat fungushyphes in die grond blykbaar baie maklik aan vertering deur bakterieë blootgestel word. Ons vind dan ook gewoonlik sterke konsentrasies van bakterieë rondom hierdie hyphes. Dieselfde het ek in grondkulture vir die Blouwier-filamente kan vasstel, waar veral die leë skedes 'n blykbaar geskikte substraat vir bakterieë vorm.

'n Ander belangrike resultaat van die direkte metode van grondwaarneming is dat die organismes soos hulle in die grond voorkom, nie altyd dieselfde vorme besit wat ons uit die reinkulture ken nie. Dit geld sowel vir die bakterieë (nl. die glomeruli) as vir die fungi. Dit hang saam met die feit dat die grond in baie opsigte 'n sub-optimale omgewing is, sowel wat betref die rykdom aan voedingstowwe en die balans daarvan, as wat betref die ruimtefaktor. Fruktifikasie van fungi is dikwels alleen moontlik op plekke waar grotere lugholtes in die grond voorkom, en dan nog mag die fruktifikasievorme ,, abnormaal '' wees. Die meeste grondfungi is, wat hulle morfologiese kenmerke betref, hoofsaaklik in reinkultuur bestudeer, en ons behoort dus die beskrywinge wat op grond daarvan opgestel is uit te brei met wat direk in die grond, of beter nog wat in grondkulture volgens Cholodny of Kubiéna se metodes waargeneem is. In 'n seker mate beteken dit 'n terugkeer, sy dit dan ook met gewysigde en vermeerderde insigte, na die mikologie van die dae van Fuckel en andere wat hulle allereers om die kenmerke van die Fungi op die natuurlike standplekke bekommer het.

Tenslotte kan die Rossi-Cholodny-metode met vrug toegepas word vir die studie van die afbraak van sekere stowwe in die grond soos o.a. deur Karnicka en Ziemiecka vir pentosane en sellulose, en deur Mollenhoff, Smith en Brown vir 'n hele reeks ander stowwe, insluitende lignien, gedoen is.

As vernaamste nadeel van die direkte metode moet genoem word dat dit in verreweg die meeste gevalle onmoontlik is om die waargenome organismes te determineer. Vir hierdie doel sal die plaat- en reinkultuur-metodes dus altyd te hulp geroep moet word. Die direkte metodes is observasioneel en nie eksperimenteel nie, en daarmee is ook hulle beperktheid gegewe.

Invloed van Mikro-Organismes op die Grond.

Die verhouding van die plant tot sy omgewing is nie eensydig in sover dat die plant as 't ware op sy omgewing parasiteer nie, dit is veelmeer 'n wisselwerking met 'n groot mate van wederkerigheid. Alleen waar die mens optree word hierdie wederkerigheid gewoonlik versteur en is dit die mens wat via die plant parasiteer op die grond! In 'n nog sterker mate as by hoër plante kom hierdie wederkerigheid en wisselwerking tussen organisme en omgewing aan die dag by die mikrobes in die grond, waar die wysiging van die omgewing deur die mikro-organismes in 'n baie kort tyd kan verloop en deur die totaal gewysigde omstandighede 'n geheel andere flora in die lewe kan geroep word.

By die toevoeging van eenvoudige en maklik afbreekbare organiese stowwe aan die grond (stysel, suikers, ureum, ens.) sal daar 'n plotselinge opbloei van 'n zymogene flora plaasvind wat slegs uit 'n beperkte aantal soorte bestaan. In die meeste gevalle sal hierdie flora na 'n kort tyd van werksaamheid terugkeer na 'n russtadium aangesien sy spesifieke energie- of voedselbron uitgeput is en die spesiale faktore vir sy aktiwiteit opgehou het

om te bestaan. Van 'n suksessie sal feitelik geen sprake wees nie.

'n Geheel ander beeld tree op wanneer komplekse organiese stowwe, soos plant- of dierreste onder gunstige omstandighede aan die grond toegevoeg word. Nou kry ons die optree van 'n ryk gevariëerde zymogene flora, met 'n duidelike suksessie in dié sin dat die eers optredende organismes die maklik aantasbare stowwe begin opbreek en opgevolg word deur vorme wat ten koste van meer resistente stowwe kan ontwikkel. Veral by die opbreek van dergelike komplekse stowwe mag daar heel wat stofwisselingsprodukte in die grond agterbly, wat op hulle beurt weer aanleiding mag gee tot verdere mikrobiale werksaamhede en ontwikkelinge. Maar na die eerste opbloei en die eerste intensiewe verloop van die suksessie, tree die latere stadia baie stadiger op en kom die mikro-populasie so langsamerhand tot sy normale stabiliteit terug.

In alle gevalle waar 'n dergelike aktiwiteit van mikro-organismes tot ontwikkeling gekom het, bly daar as resultaat iets agter in die grond, die milieu word dus verryk, eensdeels met moeilik afbreekbare reste van die oorspronklike materiaal, anderdeels met die stofwisselingsprodukte en die reste van die mikro-organismes self. Dit is hierdie dele wat so 'n groot rol speel by die ontstaan van humus.

Maar daar is nog verdere gevolge vir die grond self en dit is b.v. die invloed van die mikro-organismes op die grondstruktuur: die wyse waarop die minerale gronddeeltjies tot grotere eenhede, al of nie stabiele aggregate, verenig is. Sonder twyfel speel die kolloïdale fraksies van die grond hierby 'n uiters belangrike rol, indien nie die hoofrol nie. Maar die totstandkoming van die grondstruktuur is 'n dinamiese proses, waarby ook die ruwe organiese stowwe en hul omsettinge van groot belang is. Die fundamentele ondersoek oor die onstaan van die grondstruktuur, vernaamlik deur kolloïedchemici, het belangrike resultate opgelewer vir die grond-mikrobioloog. Hoewel daar op hierdie gebied nog baie teenstrydige of skynbaar teenstrydige opvattinge bestaan, is dit tog wel duidelik dat die uiteindelike verklaring van die grond-struktuur moet gesoek word in die gebied van die submikroskopiese dimensies. Die nuwe rigting van die mikropedologie, wat veral die grondstruktuur met mikroskopiese metodes bestudeer en hoogs interessante resultate opgelewer het ten opsigte van die mikroskopiese karakterisering van grondaggregate, grondsoorte en dinamiese prosesse in die grond, gee tog slegs 'n bevestiging van die bewering dat die *verklaring* van die verskynsels in die gebied van die ,, vernachlässigten Dimensionen " val. Ek kan op hierdie belangwekkende onderwerp nie verder ingaan nie, ek wil net kortliks aandui hoe die grondstruktuur deur die bodem-mikro-organismes kan beïnvloed word.

Die eerste stoot in hierdie rigting het gekom van die Russiese ondersoekers in die Oekraine, wat in veldproewe gevind het dat enting van grond met sekere Fungi, waaronder Trichoderma, 'n

gunstige invloed op die aggregasie uitoefen. Hoewel die resultate van hierdie eksperimente nie bo alle twyfel verhewe is nie, is deur ander werkers, vernaamlik in die V.S.A., die invloed van sekere mikro-organismes op die aggregasie van gronddeeltjies in veld- en laboratoriumproewe aangetoon. In my laboratorium het Mej. Wasserfall soortgelyke werk gedoen en dit kon aangetoon word dat hierdie gunstige invloed te danke is aan die werking van stofwisselingsprodukte van die betreffende fungi. Ons het met reinkulture gewerk en slegs in 'n enkele geval gebruik gemaak van 'n mengkultuur, naamlik 'n grondsuspensie, waarby die resultate egter minder duidelik was. Deur die werking van Fungi word die gronddeeltjies tot duidelike water-stabiele aggregate gebind. Hoe hierdie verskynsel in detail verklaar moet word, is 'n ander en baie gekompliseerde saak, waarop ek nie kan ingaan nie. Ek meen dat dit nie 'n suiwer meganiese bindingsproses deur die mycelium is nie, maar dat dit geheel op die besondere stofwisselingsprosesse van elke soort kan teruggevoer word, aangesien daar duidelike verskille in aggregasie tussen verskillende grond-fungi was, ook tussen dié wat in reinkultuur 'n opvallende ooreenkoms in groeiwyse vertoon (soos *Verticillium glaucum* en *Trichoderma viride*).

'n Ander verskynsel wat hiermee nou saamhang, is die weerstand teen natword wat sommige gronde vertoon. Ook dit het in ons eksperimente opgetree, veral na behandeling van verskillende grondsoorte met *Aspergillus terreus* (wat saam met *Verticillium glaucum* tot die algemeenste en mees verspreide grond-fungi van die Unie behoort). Ook ander fungi kan hierdie weerstand teen natword veroorsaak. Dit is merkwaardig dat hierdie verskynsel betreklik min aandag van die pedoloë gekry het: in Baver se „ Soil Physics," b.v. word wel die infiltrasiekapasiteit genoem, maar die meer fundamentele en vir die studie van grondverspoeling ongetwyfeld belangrike verskynsel van weerstand teen natword kom glad nie ter sprake nie. Die outorieteit wat hom die meeste vir hierdie onderwerp geïnteresseer het, Zunker (Breslau), het die weerstand teen natword toegeskryf aan die skutstowwe wat by afbraak van plantaardige reste, veral van grasse, vrykom. Hoewel ek hierdie moontlikheid nie wil ontken nie, moet ek tog wys op die vorming van uiters aktiewe skutstowwe wat die water-opname van die grond amper totaal belemmer, in gevalle waar aan die steriele grond, voordat dit met bepaalde fungi geënt is, net glukose as organiese materiaal toegedien is. Op grond van vergelyking met kontrole en ander eksperimente het ons tot die gevolgtrekking gekom dat die weerstand teen natword in hierdie geval moet berus op bepaalde metaboliese produkte van die betreffende fungi self. In hoever dit in die natuure 'n rol speel kan op grond van ons eksperimente nog nie uitgemaak word nie, maar dit is sekerlik werd om nader ondersoek te word.

Die invloed van grondmikrobes op die tydelike of permanente vaslegging van plantvoedingstowwe in die grond is (deur die

nadelige invloed hiervan op gewasse by sekere landboupraktyke) van so algemene bekendheid, veral wat die stikstof betref, dat ek hier nie verder op hoef in te gaan nie. Ek wil slegs daarop wys dat 'n dergelike vaslegging ook mag voorkom by sekere spoorelemente. Die proewe van Ark oor sink en van Gerretsen oor mangaan wys in hierdie rigting.

Synekologiese Aspekte.

Een van die modernste aspekte van die ondergrondse lewe is die wisselwerkinge wat daar tussen mikro-organismes onderling bestaan, in die besonder die onderlinge bevordering of remming van groei. Selde het 'n wetenskapsgebied in korte tyd so 'n geweldige opgang gemaak en so die algemene aandag getrek as die studie van die stowwe waardeur dergelike synergetiese of antibiotiese werkinge tot stand kom. Dit berus op die betreklik toevallige omstandigheid dat 'n paar van die mees bekende antibiotiese stowwe 'n sterk chemotherapeutiese werking besit teen pathogene bakterieë. Die amper magiese word ,, penicillien " het veral by die leke-publiek byna onbeperkte perspektiewe geopen. Honderde fungi is reeds, of word nog ondersoek op die vorming van antibiotiese stowwe. Hoogerheide, die skrywer van 'n resente oorsig op hierdie gebied, vergelyk die koorsagtige wyse waarop hierdie ondersoek gedoen word, nie heeltemaal ten onregte met 'n ,, wetenskaplike , goldrush ''' nie! Tog is, onder die groot aantal antibiotiese stowwe wat in korte tyd geïsoleer is, of waarvan die bestaan aangetoon of vermoed is, stowwe met gelyktydige therapeutiese werking (soos penicillien) betreklike uitsonderinge. Die meeste stowwe toon 'n groot mate van spesifisiteit in hulle werking, ander wat wel 'n sterk bakterisiede aktiwiteit ten opsigte van pathogene organismes besit, is tewens skadelik vir die menslike organismes, so dat hulle nie as geneesmiddel kan gebruik word nie. Die moontlikheid dat daar by die geweldige groot massa van fungi en bakterieë nog meer stofwisselingsprodukte met 'n bruikbare antagonistiese werking kan gevind word, bestaan natuurlik altyd. Maar Hoogerheide wys daar m.i. tereg op dat die groot moontlikhede op hierdie gebied eers dan volledig geëksploiteer kan word, wanneer die chemiese struktuur van hierdie verbindinge bekend sal wees en die aandag veral op hulle derivate kan gerig word. Dit is nie logies noodsaaklik dat juis dié stowwe wat as natuurlike metaboliese produkte van sekere grondorganismes optree, ook die grootste chemotherapeutiese waarde moet hê nie. Maar ongetwyfeld kan die bodem-mikrobiologie hier leiding gee deur die isolasie en identifikasie van stowwe wat van moontlike belang mag wees, soos dit op die oomblik reeds deur Waksman en sy skool gedoen word. Die grond sou dan nie net 'n ryke bron van nuwe vorme vir die sistematikus-mikrobioloog kan wees nie (soos ons reeds aangedui het), maar ook vir die sistematiese organiese chemikus en die farmakoloog!

Wat die betekenis van antagonistiese of synergetiese wisselwerkinge tussen bodem-organismes in die grond self betref, is die resultate nog nie so duidelik as dié wat in reinkulture of met kultuurfiltrate bereik is nie. Resultate op praktiese gebied is hier veral verkry, waar plant-pathogene fungi onderdruk of gerem is deur sekere onskadelike saprofiete. Maar in een van die nuwere oorsigte oor grond-fungi (1944) wys Waksman daarop dat vir die algemene toepassing van hierdie studies op die bodemprosesse, ons kennis nog nie ver genoeg gevorder is nie. Merkwaardig is intussen dat die aksent in die grond-biologie sterk in hierdie rigting verskuif het.

Een van die eerste Fungi waarvan die antagonistiese werking op plant-pathogene in meer detail ondersoek is, is *Trichoderma viride*. Weindling het in 1932 hiermee begin en na 'n paar jaar uit die kultuurvloeistowwe 'n toxine geïsoleer waarvan later geblyk het dat dit die selfde werking besit as die toxine van Gliocladium soorte, gliotoxine. So is daar van talryke ander grond-organismes, Fungi, sowel as Bacteria en Actinomycetes, toxiese stowwe geïsoleer wat ander organismes in hulle ontwikkeling kan rem of selfs totaal vernietig. Die mees gangbare teorie vir die verklaring van antagonistiese wisselwerkinge tussen mikro-organismes is dan ook gebaseer op die werking van dergelike toxines, maar dit sou verkeerd wees om te probeer om alle verskynsels op die manier te verklaar. So wys die resultate van Russiese werkers soos Chudiakov en Novogrudskii op die lytiese werking van sekere grond-bakterieë op pathogene fungi. In hierdie verband kan ook gewys word op die voorkoms van filtreerbare lytiese stowwe in die grond, soos dié wat as ,, bakteriofaag '' aangedui word (hoewel hulle dikwels nie net spesifiek bakterieë aantas nie, maar ook b.v. Fungi en Actinomycetes) (Demolon; Wieringa). Ook kom daar waarskynlik nie direk aan organismes gebonde enzyme in die grond voor.

Behalwe dergelike direkte aanvalle van die een organisme op die ander, moet ook die moontlikheid van konkurrensie nie uit die oog verloor word nie. Veral in die geval van *Ophiobolus graminis*, die veroorsaker van swartpootjie by koring, is daar 'n aantal gegewens wat hierop wys. Die swam is 'n parasiet wat in saprofitiese toestand slegs vir 'n beperkte tyd in die grond kan oorbly, naamlik alleen as daar sekere voedingstowwe aanwesig is. So kan Ophiobolus wel oorbly op koringstoppels of strooi, maar heel wat beter indien voldoende stikstof aanwesig is. Wanneer egter 'n sterk ontwikkeling van 'n konkurrerende mikroflora in die hand gewerk word, b.v. deur organiese bemesting, dan word Ophiobolus duidelik in sy ontwikkeling gerem. Aanmoediging van 'n intesiewe mikrobiale lewe in die grond sal dus kan bydra tot die bestryding van die parasiet. Of dit hier ook handel om konkurrensie om spesifieke groeistowwe van vitamine-agtige aard is nog nie heeltemal duidelik nie.

Naas die moontlikheid van antagonistiese werking deur konkurrensie om groeistowwe, moet ook met die moontlike onder-

linge stimulering deur mikrobiale produksie van groeifaktore, waarsonder sekere ander organismes nie kan klaar kom nie, rekening gehou word. Ons dink hierby veral aan die groeifaktore van die Bios- en Vitamine B-groep waarop 'n uitgebreide literatuur bestaan, veral ten opsigte van wat gebeur in rein- of gemengde kulture. Die gegewens oor wat in die grond plaas vind is egter nog ontoereikend om tot definitiewe gevolgtrekkinge te kom. Dat hierdie verskynsels 'n rol speel in die grond, is egter nouliks aan twyfel onderhewig.

'n Moontlike aspek van die synekologie van bodem-organismes, wat ek nie onaangeroer kan laat bly nie, hoewel ek baie min definitiefs daaroor kan sê, is die kwessie van grond-deurlugting. Dit moet toegegee word dat met alle erkenning van die gegewens wat beskikbaar is oor die samestelling van die grond-atmosfeer, en die opvattinge oor diffusie en uitwisseling met die buitelug—die beeld van daardie verskynsels vir die mikrobioloog en die plante-fisioloog nog alles behalwe bevredigend is. Sover ek kan sien vind daar in die grond feitelik geen suurstofvormende prosesse plaas nie, behalwe moontlik deur Algae, verder wys die meeste prosesse op vorming van CO_2 deur asemhaling van wortels en mikrobes, en m.i. sou daar veral in die rhizosfeer eintlik 'n ophoping van CO_2 moet plaasvind, wat die normale lewe van die plant ernstig sou bedreig. Garrett het in dié verband die remming van *Ophiobolus graminis* in die rhizosfeer toegeskryf aan die CO_2-produksie deur die saprofitiese bodemflora, maar dit is 'n punt wat nog aan kritiek onderhewig is. Daar is eintlik geen onweerspreekbare feite wat op 'n ophoping van CO_2 of 'n afname van O_2 in die normale grond wys nie. Is dit nie moontlik dat ons die verklaring hiervan kan benader deur meer aandag te skenk aan die aktiwiteit van reduserende organismes, veral nou dat geblyk het dat die CO_2-reduksie 'n verskynsel is wat baie algemener verbreid is in die lewende natuur as wat vroeër gemeen is nie? Die feit dat CO_2 'n noodsaaklike faktor is vir sommige stofwisselingsprosesse van aërobe bakterieë en fungi, mag in hierdie rigting wys. Ek wil dit slegs as 'n suggestie noem waarvan die moontlike gevolge nader ondersoek dien te word. Op grond van ons huidge kennis van hierdie CO_2-reduksie sou dit egter hoogtens redenskap kan gee van 'n vermindering van CO_2, aangesien die tans bekende reduksieverskynsels feitelik sonder vrystelling van suurstof plaas vind.

Die Wortels van Hoër Plante.

Ons kan selfs 'n sketsmatige beeld van die grond as omgewing nie as adekwaat beskou as ons nie kortliks die aandag vestig op die ekologie van die onderaardse dele van hoër plante nie. As sodanig kom feitelik net die wortels self in aanmerking omdat van alle ondergrondse dele alleen hulle in 'n voortdurende direkte wisselwerking met die grond staan. Hierdie wisselwerking tussen wortels en bodem kan van vier verskillende kante beskou word, naamlik; die wortels self, die wisselwerking tussen wortels, die

invloed van die wortels op die grond, en die wisselwerking tussen wortels en mikro-organismes. Ek sal slegs sekere aspekte van die eerste punt hier bespreek, en die derde en die vierde punt saam vat by die bespreking van die rhizosfeer. Die tweede punt moet om redes van plaasgebrek buite bespreking bly.

WATER- EN SOUTOPNAME.

As gevolg van dié in die 19e eeu ingevoerde waterkultuurtegniek, waardeur so'n groot ontwikkeling van die voedingsfisiologie van die plant moontlik was, het die begrip ,, grondoplossing '' onstaan. Die aanname dat die water- en voedselopname deur die plant uit die grond op die selfde wyse sou plaasvind as uit 'n voedingsoplossing, het, mede deur die optree van ooreenkomstige gebreksimtome, voor die hand gelê. Die noodsaaklikheid van water met die daarin opgeloste stowwe, en van lug (suurstof) in die grond, die intensiewe verbinding van die sterk plastiese wortelhare met gronddeeltjies van verskillende aard, het aanleiding gegee tot die onstaan van die beeld soos vasgelê in Sachs se bekende afbeelding van wortelhare in die grond (Handbuch, 1865) wat nog tot 1931 (en moontlik later) in grotere handboeke oor plantefisiologie voorkom. Hiedie afbeelding is miskien een van die eerste belangrike mikropedologiese figure, en vertoon die lug as 'n aantal selle of blasies tussen gronddeeltjies van verskillende grootte, wat almal omgewe is deur 'n saamhangende geheel van dun watervliese, voorwaar 'n ideale toestand wat slegs in 'n minderheid van gevalle sal verwesenlik word. Eers in latere jare het hierdie beeld ingrypende wysiginge ondergaan onder die invloed van die meer selfstandige ontwikkeling van grond-fisika en mikropedologie.

Die opname van water uit die grond deur die wortels van die plant kan hier slegs kortliks aangestip word. Hoewel osmose nog altyd as die proses beskou word waardeur wateropname plaasvind, is dit duidelik dat hierdie opname nie 'n meganiese proses is nie, maar dat dit 'n lewensverskynsel is wat van faktore soos suurstofaanwesigheid, narcotica en andere afhanklik is. Naas die hoeveelheid en toestand van die water in die grond, speel ook die grondtekstuur en- struktuur 'n belangrike rol by die wateropname. Op die betekenis van die plantewortels vir die beweging van water in die grond en die pedologiese konsekwensies daarvan, het Russell 'n aantal jare gelede gewys. Die verband tussen waterbeweging onder die invloed van wortels en struktuurvorming is onder andere deur Bradfield beklemtoon.

Wat die opname van soute deur die wortels betref, het ons opvattinge in resente tyd belangrike wysiginge ondergaan. Nog in 1924 het Benecke in die vierde druk van Jost se ,,Vorlesungen'' (bls. 131) die kategoriese uitspraak gedoen (deur homself gespasiëer): ,, Bei dieser Aufnahme gelten die Gesetze der Osmose, und sie regeln Qualität und Quantität der Asche.'' Dit het egter spoedig daarna duidelik geword dat eenvoudige osmotiese wette nie die gekompliseerde soutopname-proses kan

verklaar nie (om die later opkomende stryd oor die bepaling van die begrip osmose nog maar nie te noem nie). Die feit dat die beweging van soute tussen wortel en grond in baie opsigte 'n dinamiese ewewig vertoon, soos nog steeds deur moderne eksperimente bevestig word, het aanvanklik die aandag afgelei van die tipies vitale aard van hierdie proses. Nòg die absorpsiewette, nòg die verskillende permeabiliteitsteorieë was in staat om die opname van verskillende soorte van ione uit die grond bevredigend te verklaar. Twee moderne gesigspunte moet veral op die voorgrond geplaas word, die reeds genoemde vitale aard van die ion-opname en die ontoereikendheid van die grondoplossingsteorie om *alle* verskynsels te verklaar.

Van verskillende kante (Steward, Hoagland, Lundegardh) is die verband tussen asemhaling en ion-opname beklemtoon. Hoewel die teorieë op hierdie gebied nog geensins met mekaar versoen is nie, blyk tog dat in die meeste gevalle voedingstowwe opgeneem word ten koste van opoffering van energie deur die lewende plant. Buitendien vind hierdie opnameproses plaas in duidelike samehang met die inwendige metabolisme van die wortel, in die besonder met die vorming en omsetting van organiese sure.

In nou verband hiermee staan die nuwere opvattinge dat die grondkolloïede 'n rol kan speel by die opname van soute deur die wortels, met ander woorde dat daar kontak- en uitwisselingsreaksies sou plaas vind. Jenny, Overstreet en hulle medewerkers het wel die belankrikste stoot aan hierdie opvatting gegee. Hierdie kontak-uitwisseling word vernaamlik tot stand gebring deur die H^+-ione wat deur die plant afgeskei word in verband met die asemhaling en (of) vorming van organiese sure. Die H^+-ione kan dan, in kontak met grondkolloïede waaraan ander katione geabsorbeer is, teen hierdie katione uitgewissel word en so kan die laastes dan deur die plant opgeneem word. Daar is voldoende aanwysinge om te laat aanneem dat altans 'n deel van die plantvoeding op hierdie wyse verloop, hoewel vir die verklaring van sekere verskynsels, onder andere wat betref die anion-opname, die grond-oplossing nog geensins oorbodig geword het nie.

Die Rhizosfeer.

Die laaste belangrike aspek van die wortels van hoër plante in die biocoenose van die grond wat ek hier wil noem, is die vraag na die assosiasie van die wortels met mikro-organismes. Ook hier moet ons weer sketsmatig wees en die hele vraagstuk van mykorrhiza, hoe belangrik ook, buite bespreking laat. Ook die pathogene organismes kan slegs kortliks genoem word.

Die direkte omgewing van die wortel, die rhizosfeer dring hom, by die toepassing van direkte ondersoekmetodes, vanself aan die waarnemer op as 'n by uitstek geskikte medium vir die groei van mikro-organismes van verskillende aard. Kwantitatiewe bepalinge toon aan dat die aantal organismes afneem met die afstand van die wortel, op so 'n manier dat direk op die

worteloppervlak self 'n baie ryk flora voorkom, dan volg 'n gebied in die onmiddellike omgewing met nog 'n groot aantal organismes, terwyl op enige afstand van die wortel die aantal belangrik kleiner word.

In die algemeen is daar betreklik min kwalitatiewe verskille tussen die rhizosfeer en die gebied op enige afstand van die wortel: dit is (met enkele uitsonderinge) meestal dieselfde organismes wat voorkom. Maar kwantitatief bestaan daar wel groot verskille in dié sin dat die getalsverhoudinge tussen die komponente van die populasies sterk verskillend mag wees, ten eerste in die rhizosfeer self en in die grond daarbuite, en ten tweede ook in die rhizosfere van verskillende plante. Of die resultate wat deur ondersoekers in verskillende lande by verskillende plante verkry is, gegeneraliseer mag word, is 'n oop vraag wat waarskynlik wel ontkennend beantwoord moet word. Lochhead vind in die rhizosfeer onder die bakterieë vernaamlik die biochemies meer aktiewe vorme, terwyl verderop in die grond vorme gevind word wat meer tot pleomorfie neig. Thom wys daar op dat die organismes in die rhizosfeer veral te doen het met die afbraak van ruwe organiese materiaal, terwyl dié wat leef ten koste van meer resistente stowwe (humus) ontbreek. Die bevinding van Timonin dat in die rhizosfeer by Fungi en Actinomycetes die vegetatiewe groei oorheers, terwyl verderop meer spoorvorming aangetref word, is hiermee nie in stryd nie.

Verskillende skrywers stem verder ooreen in die opvatting dat die afsterwende dele van wortels (wortelmussie, buitenste sellae, wortelhare, ens.) 'n uiters geskikte substraat vir mikroorganismes vorm. Die aantalle bakterieë en fungi is hier dan ook besonder groot. Garrett het hier 'n besondere mikrosuksessie waargeneem, waar die wortelparasiete gewoonlik voorafgaan, om gevolg te word deur 'n hele reeks van saprofiete. wat tenslotte wortel met parasiet en al aan afbraak mag onderwerp.

Tog is met die verskaffing van dooie organiese materiaal deur die wortel die probleem nog nie geheel en al uitgeput nie. Sonder twyfel speel ook wortel-uitskeidinge 'n belangrike rol. Van watter aard die wortel uitskeidinge mag wees, is in die meeste gevalle nog 'n omstrede vraag, maar soms is duidelike aanwysinge hieromtrent voorhande. Hoogswaarskynlik is hulle van verskillende aard by verskillende plantesoorte. 'n Merkwaardige en belangrike resultaat is deur Timonin verkry in verband met die wortel-uitskeiding by vlasvariëteite wat onderskeidelik gevoelig en resistent is ten opsigte van *Fusarium lini*. Die resistente variëteit skei naamlik geringe hoeveelhede blousuur (HCN) uit in die omgewing (25-37 mg. per plant in 450 ml. voedingsoplossing), terwyl die uitskeiding by gevoelige plante minimaal is. Dit blyk nou dat HCN in die voorkomende konsentrasie remmend werk op sekere parasitiese fungi (soos *Fusarium culmorum* en *Helminthosporium sativum*), terwyl dit stimulerend werk op saprofiete soos *Trichoderma viride*. Vir die waargenome

kwantitatiewe verskille in die mikroflora van die rhizosfeer van resistente en gevoelige variëteite is dus die deur die wortels uitgeskei HCN verantwoordelik.

Russiese ondersoekers, met name Krasselnikov, Kriss en Litwinov, het die periodisiteit van die rhizosfeer-organismes ondersoek en gevind dat twee maxima optree, naamlik by die eerste ontwikkelingstadium van die wortels en later wanneer die plant vrug dra. Die laaste periode kom op 'n merkwaardige wyse ooreen met Deleano se waarneming van sterke uitskeiding van anorganiese soute deur die wortel in die periode wat op die blomtyd volg. Of hier werklik 'n direkte verband bestaan, kan deur die verskillende omstandighede en doelstellinge van die proewe nie sonder meer gesê word nie.

Die verband tussen rhizosfeer-organismes en grondsuurheid moet hier kort vermeld word. Sommige ondersoekers skryf die betekenis van die rhizosfeer-fungi vernaamlik toe aan hulle suur-afskeiding en aan die mobilisering van reserwestowwe in die grond as gevolg daarvan (b.v. Jahn vir wat hy die ,, peritrofe mykorrhiza " noem). Ook Kürbis (1937) wys op die voorkoms van vernaamlik suurvormende fungi in die rhizosfeer. Wanneer hy egter ook *Verticillium glaucum* in dié verband noem en verduidelik dat hier skommelinge in die pH optree, dan moet ek net wys op die resultate van Z. V. Smit in my laboratorium, naamlik dat *Verticillium glaucum* blykbaar aan die ammonium-ion voorkeur gee bo die nitraat-ion. Op 'n voedingsbodem met $NaNO_3$ as N-bron tree 'n alkaliese reaksie op, terwyl met NH_4NO_3 as N-bron, die nitraat-ion agterbly en die pH kan daal tot 1.5. Mej. Wasserfall het in gesteriliseerde grond na enting met hierdie fungus, steeds 'n verskuiwing van die pH in alkaliese rigting waargeneem. Aan die grond was slegs K_2HPO_4 en $(NH_4)_2HPO_4$ toegevoeg.

Aan die ander kant wys Thom en Humfeld op die vermoë van die wortels self (byvoorbeeld by mielies) om in spesifiek sure of alkaliese gronde die pH te handhaaf in die nabyheid van die neutrale punt (6-7.5), sodat hulle op die manier 'n gunstige omgewing kan skep vir die voorkoms van die spesifieke rhizosfeer-fungi.

Ook hier blyk dus weer dat daar baie faktore is om rekening mee te hou en dat nie alle reaksies van mikro-organismes ten opsigte van plantewortels aan een enkele faktor kan toegeskryf word nie.

In talryke publikasies oor die invloed van plante op die struktuur en aggregasie van die grond, word op die betekenis van wortels (veral van graswortels) vir die struktuurvorming gewys. Ongelukkig ken ek geen publikasies op hierdie gebied wat spesiale aandag aan die mikro-organismes van die rhizosfeer gewy het nie. Die besondere talrykheid van mikrobes in die rhizosfeer en die stimulerende werking van plantewortels op hulle ontwikkeling, maak dit egter baie waarskynlik dat 'n groot deel

van die invloed van die wortel op die grond-aggregasie aan die organismes van die rhizsfeer moet toegeskryf word.

BESLUIT.

Ek vrees dat ek reeds te baie van u aandag geverg het, en tog het die beeld van die ondergrondse biocoenose wat ek vir u geskets het, onvolledig gebly. Daar is baie sake wat ek om verskillende redes weggelaat het, ek vra geen verskoning daarvoor nie. Maar afgesien daarvan glo ek nie dat dit, by die huidige stand van ons kennis, moontlik is om 'n volledige ,, oecologia subterranea '' te gee nie. Dit was dan ook slegs my bedoeling om 'n aantal belangrike en belangwekkende punte uit die gebied na vore te bring. Hoe baie ook al tot nou toe bereik is, tog moet ons erken dat daar nog meer probleme voor ons lê, nie net vir detailondersoek nie, maar ook daar waar op verskillende punte die groot lyne nog vasgestel en deurgetrek moet word.

Dit is wel onnodig om u te oortuig van die praktiese belang wat die aangeroerde vraagstukke het vir die grondbeheer in die ruime sin van die woord. Miskien het u van my verwag dat ek meer nadruk op die praktiese aspekte van die bodem-biologie sou gelê het. Maar ek het met opset geprobeer om in die eerste plek die meer fundamentele feite en beginsels te beklemtoon en 'n, sy dit ook onvolledige, totaalbeeld van die grond-ekologie te gee. Want geen wetenskap kan hom harmonies ontwikkel as hy homself net rig op die oplossing van praktiese probleme en die teoretiese fundering en waardering van sy ontdekkinge agterwee laat nie. Hierdie punt moet veral in Suid-Afrika sterk beklemtoon word, waar nog altyd so baie utilitaristies en uitsluitend prakties georiënteerde belangstellendes en belanghebbendes hulle menings uiter oor die rigtinge wat navorsingsinstitute en universiteite in die toekoms moet inslaan. Ons mag geen onderskeid maak tussen ,, suiwere '' en ,, toegepaste '' wetenskap, of tussen fundamentele probleme en die toepassing van algemene beginsels en wette op spesifiek Suid-Afrikaanse toestande nie, en veral nie in dié sin (soos ek al gehoor het dat ,, akademici '' dit verkondig), dat die studie van fundamentele vraagstukke maar liewers oorsee moet gedoen word, omdat Suid-Afrika op een of ander manier nie die geskikte land daarvoor sou wees nie! Daar is ongetwyfeld baie praktiese probleme wat om 'n direkte oplossing vra, en daar is ook baie wat fundamentele navorsing in Suid-Afrika moeiliker maak as elders. Maar tog mag vir die harmoniese ontwikkeling van die natuurwetenskap in Suid-Afrika die fundamentele ondersoek nie uit die oog verloor word nie. Dit geld in die allereerste plek vir die universiteitsinrigtings, wanneer ons ten minste wil hê dat hulle hul funksie ten opsigte van die kultuur in die toekoms sal bly vervul en nie tot vakskole sal ontaard nie. Alleen deur 'n harmoniese verhouding en 'n dinamiese ewewig tussen fundamentele en toegepaste wetenskap sal die land waarlik en blywend gedien word.

South African Journal of Science, *Vol. XLII, pp. 62-69, June, 1946.*

REVOLUTION IN EVOLUTION

BY

Professor C. J. van der Horst,
University of the Witwatersrand, Johannesburg.

Presidential Address to Section "D" of the South African Association for the Advancement of Science.

Read 4th July, 1945

When, after the appearance of Darwin's Origin of Species the principle of evolution was more generally accepted, it was the common opinion amongst biologists that the development of plants and animals by evolution was an exceedingly slow process. In this respect there was no difference between the adherents of Darwin's theory of passive selection or of Lamarck's theory of active adaptations. And, by the way, I feel more inclined towards Lamarck's theory, or at least to the general principle that it involves. Evolution is not something accidental, the work of circumstances outside the organic world, the result of a passive selection by lifeless, inanimate nature amongst minute, haphazard variations of animals or plants. Evolution is an active principle; it is an innate characteristic of a living organism to progress and to adapt itself to ever-changing circumstances; life reveals itself in an endless variety of forms and advances continuously in a never-ending struggle.

However, no matter whether Darwin's or Lamarck's theory was accepted, in the early days of this epoch in the history of Biology, it was the general opinion that evolution had proceeded in an exceedingly slow and very gradual way. As long as the geologists had not made a more or less accurate estimate of the duration of the successive geological periods, the biologists had a free hand and could assign hundreds or thousands or millions of years to the phylogenetic development of even the smallest alteration in the hereditary characters.

It was only towards the end of the last century and the beginning of the present that a different idea gained the field mainly under the influence of Hugo de Vries. He found that rather large and conspicuous changes may sometimes occur suddenly in plants. In his experiments he showed that such mutations were hereditarily fixed, and were transmitted to the offspring from generation to generation in the same form in which they first appeared in the parents. Although the even-

ing primrose, the plant with which he mainly experimented, later on proved to be a very unsuitable example to use in support of his view, nevertheless the general conclusion of Hugo de Vries concerning evolution by sudden mutations was widely accepted and confirmed by many scientists.

During the course of his investigations Hugo de Vries rediscovered the laws of Mendel. This fundamental work was overlooked for thirty years because it was published in the inaccessible year book of a cloister. Once these laws were made widely known, they stimulated new research, and modern Genetics became a special branch of biological Science. The results of Genetics give ample and indisputable evidence of the validity of de Vries's contention that rather large and conspicuous variations may suddenly arise in the hereditary pattern of animals and plants, although his wider aim, to show that evolution takes place by these sudden leaps is often lost sight of by geneticists.

By mutation a new character, not previously encountered in the organism, may suddenly appear. The changes may be positive or negative. Existing characters may be lost by mutation no matter whether such a character was useful or not or was even necessary for the organism. These loss-mutations can, therefore, become very dangerous. Positive mutations, the sudden creation of something new, have also been observed, and small as they are or appear to be they may be of the utmost importance for the progress of the organic world. Their sudden occurrence gives them a revolutionary character in the evolution of life.

This does not imply that something really new is always created. Mostly something already in existence is affected and may sometimes change gradually step by step, and at other times by leaps and bounds. The creation of something definitely new seems to be a rare phenomenon; yet occasionally it happens. In the following pages I shall endeavour to illustrate these forms of organic progress from a study of the comparative anatomy of the vertebrate animals.

Comparative anatomists are by nature real conservatives. It is their aim to study the phylogenetic history of some organ in all its transformations, it is their glory and delight to trace back successfully some organ of the higher vertebrates to its earliest beginning in lower groups of this phylum. Even the human cerebral cortex, which we may consider as the highest manifestation of organic life, was compared with similar structures in the brain of reptiles and amphibians and finally found by Holmgren in its most humble form in the embryonic dogfish. Comparative anatomists only find rest and satisfaction if they can unravel the complete history of some organ from its origin in the lower vertebrates, or even better in Amphioxus, up to its final form in the mammals and in man. Notwithstanding all transformations in form and function such an organ remains

fundamentally one and the same. Its external appearance may altar, its essence as manifested by its origin and subsequent development is and remains always the same. Comparative anatomists, conservatives as they are, would abhor something completely new. Without doubt, their indefatigable research and their conservative methods and inclinations have yielded considerable results.

The phylogenetic history of the upper and lower jaws of the sharks, called respectively the palato-quadrate and the Meckelian cartilage in comparative anatomical terms, may serve as an example of the remarkable achievements reached in this branch of Zoology. Armed with a formidable row of teeth they serve their purpose well as everybody knows. Yet in the higher fishes and in amphibians their function is already taken over by other parts of the skeleton; the jaw bones found in higher vertebrates are structures fundamentally different from the cartilaginous jaws of the sharks. Even so, these original jaws of the vertebrates have not disappeared; in early embryonic life they show the typical form of jaws even in the highest vertebrates. The transformation of the upper jaw is more profound that that of Meckel's cartilage, and its history was only established after long and careful study. In reptiles we see that the greatly reduced anterior part of the original jaw becomes incorporated in the palate. the middle part is found in a bone called the epipterygoid, and the posterior end, now the quadrate bone, retains to a certain extent its original function in so far as that the lower jaw articulates with it. Meckel's cartilage, although surrounded by other bones, still forms an integral part of the lower jaw; its posterior end ossifies and becomes the articulare. If we take the mammals into consideration the picture again changes completely. The anterior part of the palato-quadrate has nearly disappeared. But the middle part is greatly extended and appears now in the form of a large bone, the alisphenoid, lying at the back of the eye socket and participating there in the formation of the braincase. The posterior end of the upper jaw of the sharks, the quadrate bone of the reptiles, has changed so completely that its original character was only established after a careful study of its embryological development. With the hind end of the lower jaw it has been transformed in mammals into tiny ear ossicles, the hammer and the anvil.

This remarkable result of embryological research was confirmed by a comparative study of the famous fossils from the Karroo which form a connecting link between the reptiles and the mammals. In the oldest of these Karroo fossils the reptilian structure is still retained in its original form. But in later forms we find a gradual transition to the mammalian type. The posterior end of Meckel's cartilage becomes reduced to a small bone and the lower jaw establishes a new joint directly with the skull. In some intermediate forms the old articulation right at

the posterior end of the lower jaw is still there and it is functioning, but the new hinge, more frontal, is already established. The objection was made that two articulation points, one in front of the other, were a mechanical impossibility, which objection only shows a lack of mechanical insight. If the one joint is convex and the other is concave, they can exist and function simultaneously. And so it is found in the mammal-like reptiles, the old joint is concave and the new convex.

The unravelling of the phylogenetic history of the Selachian jaws is one of the triumphs of comparative anatomy. This history shows that one and the same structure may occur in all vertebrates; it may appear in new forms, it may assume new functions, yet in essence it remains the same old structure.

Among all animals only the birds and mammals have a constant body temperature, independent of and mostly well above the outside temperature. This high temperature is maintained by an intensification of the metabolism as compared with the lower cold-blooded vertebrates. However, this high metabolism is not enough to regulate the body temperature; in order not to lose warmth the body must be covered by a dense and insulating layer. Such a layer must form a part of the body, yet it must itself be insensitive to temperature changes or in other words it must be dead. Nor must it hamper the animal's movements. Being situated at the surface of the body it is subjected to continuous wear and tear, therefore, being dead itself it must easily and constantly be replaced. This difficult problem was solved by the birds and mammals independently and in two different ways, birds developing feathers and mammals hairs. The birds may have adopted the more ingenious method since their covering not only keeps the body warm but provides them with the means for a new method of locomotion.

Comparative anatomy shows that the birds in the evolution of the feathers made use of an old organ, existing already in their ancestors, the reptiles, namely the scales. There would appear to be a vast difference between a peacock's feather and a lizard's scale, yet a feather is nothing other than a very elongated and intricately branched horny scale. One can find all gradations between these two structures in birds, and the scales apparently can easily be transformed into feathers as is demonstrated by the legs of pigeons and fowls which in some varieties are covered with scales and in others with a dense coat of feathers.

But what are the hairs found in the mammals? In their formation and structure the hairs are fundamentally different from feathers, although some simplified types of feathers may superficially assume the outward appearance of hairs. Hairs are found in all mammals in their typical form, except in whales where they are lost secondarily. However in no other class of the vertebrates is a single organ found that bears enough

resemblance to hair to be regarded as the original form from which hair might have developed in the course of evolution. Comparative anatomists could not find any satisfaction or rest of mind until such a predecessor of hair was found. Numerous attempts were made to homologise various organs found in lower vertebrates with mammalian hair. Leydig compared hair with the pearl organs temporarily found in carp and other fishes. Emery tried to deduce the origin of hair from the dermal denticles of the Selachians, Brandt from the teeth in the mouth of all vertebrates. Van Kampen compared hair with the femoral pores found in lizards and derived both from the dermal holocrine glands of the Amphibia. According to Maurer, whose opinion found most supporters, the lateral line sensory organs of fishes and aquatic Amphibia were the forerunners of mammalian hair; when the Amphibia became terrestial animals the supporting cells of these organs should have multiplied profusely and given rise to hair. However, these sensory organs, unlike hair, are very restricted in their distribution on the body and when the present day Amphibia after metamorphosis leave the water to live on land their sensory organs disappear completely and are never seen to change into anything even remotely resembling hair.

None of all these hypotheses about the origin of hair can pass the test of impartial criticism. That hair may bear some similarity to other cutaneous organs is not surprising, since all these organs are formed by the same rather simply and uniformly constructed integument. With Botezat we can only come to the conclusion that the mammalian hairs are organs formed by the epidermis independently of any other organ found in lower vertebrates. When the acquisition of a constant body temperature made it necessary for the mammals to protect their body with an insulating layer something completely new was created. At least that is one way of expressing it. Another way is to say that the creation of an insulating layer in the form of hair made the acquisition of a constant temperature possible. However, no matter which view is preferred, the formation of hair was something entirely new in the evolution of the vertebrates, it was a step of a definitely revolutionary character.

Another characteristic of most mammals is that they give birth to living and fully developed young, instead of laying eggs like the majority of vertebrates. Unlike the possession of hair this characteristic feature has evolved only after the class of the Mammalia had already been established. The most primitive living mammals, the Monotremes represented by the duck-billed platypus and the spiny anteater of Australia, lay eggs after the fashion of reptiles and birds. The next order, that of the Marsupials, shows a stage of transition in this respect that the young are born in a very imperfect stage of development. In all other mammals the egg develops within the uterus of the mother and the young are born alive and fully developed.

This change in the method of reproduction had first of all a great influence on the size of the egg. When in reptiles and birds the eggs are laid and the embryo develops inside the egg but without contact with the mother, it is necessary that the egg when laid should be provided with all the food required during development. These eggs, therefore, are very large and moreover the size of the egg is determined by the size of the particular species of bird or reptile. In mammals, however, the developing embryo inside the uterus is fed by the mother. The egg contains only a small amount of yolk to provide food for the first stages of development before the embryo is well lodged in the uterus. Mammalian eggs, therefore, are small, about 0·1 mm. and that irrespective of the size of the animal. So the mammalian embryo from a very early stage onwards has to extract its food from the maternal tissues. For this purpose a differentiation of the embryonic cells already takes place at a very early stage of development when the embryo consists of a simple ball of cells only. The surface cells of this ball arrange themselves into a regular layer surrounding a central mass of cells. The embryo proper will develop from this central mass only and the outer layer of cells, being in direct contact with the maternal tissues, extracts the food from the uterus and passes it on to the embryo. Hubrecht called this outer layer of cells the trophoblast or feeding layer and this name has been generally accepted by embryologists.

Now here was an interesting question for comparative anatomists to solve. What is the nature and origin of that trophoblast?

It is a general rule in embryological development that the phylogenetically older and more important organs are formed first of all to be succeeded at later stages of the development by the organs acquired in the less remote past of the phylogenetic history of the animal. So we see that in vertebrates the notochord, inherited from the pro-vertebrates, is the first organ to be formed during development and it is immediately followed by the formation of the central nervous system, also an organ of long standing.

In mammals the trophoblast is the first organ to be formed, so it was natural for comparative anatomists to go back to remote antiquity to find the predecessor and the phylogenetic origin of the trophoblast. Hubrecht, famous not only for his splendid work in the field of mammalian embryology but also for his rich imagination, saw in the trophoblast an old organ inherited by the mammals from early aquatic vertebrates where it served as a protective envelope for a free swimming larval form and he even compared it with a similar envelope found in the larvae of the Nemerteans, a group of primitive worms. In reptiles and birds Hubrecht could only find some traces of the mammalian trophoblast, but in Amphibia and the bony fishes the vestiges of this organ should be much clearer. On the other hand, in sharks, cyclostomes and Amphioxus the tropho-

blast was absent altogether. In order to explain these findings Hubrecht tried to turn the whole phylogenetic history of the vertebrates, as this was and still is generally accepted, topsy-turvy and he assumed that the mammals had arisen directly from pro-tetrapodous aquatic ancestors; the reptiles and birds with their large eggs should form only a side branch and the Amphibia should have assumed aquatic habits during their endeavour to become mammals. The sharks, cyclostomes and Amphioxus were placed outside the phylogenetic history of the other vertebrates altogether. Most interesting as these speculations are, they did not find many adherents, but at any rate they show the lengths to which a comparative anatomist will go in his quest for ancestral forms.

However, most embryologists are of the opinion that the early development of the mammals can only find a plausible explanation by deriving it from that of the reptiles and especially since the fundamental research of J. P. Hill on the development of the marsupials the problem of the origin of the trophoblast seems to have been clarified.

In reptiles only a tiny spot on the periphery of the egg will form the real embryo. The huge yolk mass will be covered by a layer of cells derived from the embryo, but this layer, known as the extra-embryonic ectoderm, is only a temporary feature and, together with some other membranes, will be discarded at birth. In marsupials Hill found that there is still a certain amount of yolk but it is so much reduced as compared with the reptiles that the embryonic part in early development has about the same extent as the extra-embryonic ectoderm. Hill compared the trophoblast of the higher mammals with this extra-embryonic ectoderm and it must be admitted that at certain stages of development the similarity is indeed striking. However, there is something illogical in this assumption. In reptiles with their huge amount of yolk the extra-embryonic ectoderm covers by far the greater part of the egg and the embryo proper occupies a tiny segment only. In marsupials the amount of yolk is only small and in consequence the extra-embryonic ectoderm is reduced to half the surface of the egg. In higher mammals there is practically no yolk at all and yet if the extra-embryonic ectoderm should now, according to Hill, cover the whole egg, it would be relatively larger than even in the reptiles. It would be more logical to assume that with the total loss of the yolk the extra-embryonic ectoderm had disappeared completely. But then the trophoblast cannot be homologous to the extra-embroyonic ectoderm.

What then is the trophoblast?

Elephantulus, that remarkable small and primitive mammal, which occurs quite abundantly in South Africa, gives the answer to this question. Unlike other higher mammals in which a massive ball of cells is formed in the first developmental stages we see that in Elephantulus the first divisions of the

egg cell result in the formation of a hollow sphere, in appearance like the sphere found in marsupials. However, the wall of this sphere is not, as in marsupials, divided into an embryonic and an extra-embryonic half; it is all embryonic or in other words the extra-embryonic or yolk ectoderm of the marsupials and reptiles has disappeared completely. By further cell division the inner cell mass, from which the embryo proper will be formed, is differentiated and the outer layer only now assumes the character of a trophoblast.

In other mammals this trophoblast is differentiated at an earlier stage of development before the central cavity of the egg is formed. In Elephantulus, as in marsupials, this central cavity is formed first and only then is the trophoblast differentiated. Therefore, the trophoblast is not homologous to the extra-embryonic ectoderm of the reptiles, nothing like it is even encountered in the marsupials. When with the extension of intra-uterine life and the consequent loss of the yolk mass the need for a feeding mechanism arose in the higher mammals, the trophoblast was created as an entirely new organ of which not even a trace can be found in any of the lower vertebrates. A step of a definitely revolutionary character was made in the phylogenetic history of the animals.

In the constant effort to reach higher forms of organic life, and this striving is an innate characteristic of living nature, old and redundant organs are often ruthlessly discarded. Comparative anatomy shows that, once an organ has become useless, it may disappear without leaving a trace. This principle is evident on a much grander scale in the evolution of the animal kingdom as a whole. Whole groups of animals have in succession appeared, flourished, and disappeared again, leaving us nothing but their often impressive fossil remains. They had played their role in organic evolution and then died out to make room for other and higher forms of organic life. Nature is not, however, always so drastic, it is often very conservative. Whenever a good use can be made of some organ, it is not discarded. It may change by gradual evolution into a more perfect form, as the birds' feathers show; yet it remains in essence the same old organ adapted to a new function. In the same way not all animals of previous ages have died out without leaving a trace. Some succeeded in adapting themselves to the ever-changing world, they gave rise to new and higher forms of life and their descendants exist at the present day. This striving of living nature towards ever higher expression could mostly be met by a continuous and slow evolution in small and unobtrusive steps. But whenever completely new circumstances are encountered, organisms are capable of creating something entirely new; they do not shrink from acting in a revolutionary way in their strivings for perpetual and irresistible progress.

South African Journal of Science, *Vol. XLII, pp. 70-83, June, 1946.*

SOME PROBLEMS OF BANTU LANGUAGE DEVELOPMENT

BY

Professor G. P. Lestrade,
University of Cape Town.

Presidential Address to Section E of the South African Association for the Advancement of Science.

Read 2nd July, 1945.

The question of the future of the Bantu languages, important and urgent as it is in its bearing upon the cultural future of the Bantu-speaking peoples, has so far received neither the amount nor the kind of attention to which it is entitled. I believe it will be readily admitted that the number of people seriously concerned about Bantu welfare in general is far smaller than it ought to be. The number of those really interested in problems of Bantu linguistic welfare in general, and in the future development of the Bantu languages in particular, constitutes but a modest proportion of even this none too grand total. Again, such attention as has been bestowed upon the problems involved—the formulation of policy and its execution in practice—has not been guided by the quantity and quality of discussion, or characterised by the comprehensiveness and vigour of action, which are demanded by the complexity and difficulty of the issues on the one hand, and their importance and urgency on the other.

In the hope of helping in some small measure to bring about a change in this state of affairs, I shall venture in the present instance to attempt three things. In the first place, I shall endeavour to arouse some interest in and some concern regarding these problems on the part of a greater number and a wider range of people than has been the case hitherto. Secondly, I shall try to make some contribution towards that more extensive and intensive discussion of which these questions are in need and to which they have a right. My third aim will be to urge, in regard to these matters, more definite direction in our policies, and greater drive in our actions.

Partly of necessity and partly from choice, I shall concern myself in the main with those Bantu languages that are found in South Africa. I am aware that this limitation puts a yet further restriction upon any validity which my arguments and conclusions may have: I venture to believe, nevertheless, that they will be found to have some bearing upon the case of other Bantu and

perhaps even non-Bantu languages spoken elsewhere in Africa. Again, in a general paper of this kind I cannot hope to cover the whole, even of my restricted field, nor can I claim to offer none but new and original material. I can only endeavour not to make my treatment too sketchy or too one-sided, and trust that at least a reasonable proportion of what I have to say will be found to be fresh in itself, or in its setting, or in both.

The two main parts into which I propose to divide my discussion of the problem are determined by two general and fundamental questions which govern it. These are.

(1) Ought all or any of the South African Bantu languages to survive at all, and, if so, what part ought they to play in the life of our Bantu-speaking peoples?

(2) How can we best assure that such languages as we think ought to survive should play the part we think they ought to play?

To each of these questions many different replies are possible, and have actually been given at least in theory by different schools of opinion. For the purposes of this discussion it will be both necessary and convenient to group these replies into three main categories, which for brevity's sake I shall here call the discouraging, the encouraging, and the reserved.

Let me examine each of these briefly. It is held in some quarters, both inside and outside South Africa, that the languages of more or less primitive peoples, in subjection to at least self-styled civilised nations, neither can nor should survive at all. The cultural, economic and political odds against their having any hope of doing so except at the cost of a very large amount of more or less artificial fostering are, this school believes, too great; and even if it were possible to keep these languages alive somehow, the effort involved would not only not be justified, but would also actually deserve condemnation. If any of the African languages could manage to drag on some miserable sort of existence, they would merely continue to do what they are doing now, i.e. to bind their speakers to the culture from which they ought to emancipate themselves, and to continue to act as a drag upon the speakers striving to attain a more advanced culture and to adapt themselves to the superior environment of their rulers. That culture the Africans must make their own if they are to take a worthy place in that environment; and the way to this lies, in at least some measure, and perhaps in a very large measure, through the Europeans' language. Our Bantu-speaking peoples, then, should as soon as possible abandon their own tongues and adopt the speech of the white man, with all its cultural traditions and resources, and with all its economic and political advantages. Our policy towards the Bantu languages should therefore be plain. We should not attempt to repress them actively, since that, as has happened many a time

in the linguistic history of the world, might serve as an indirect means of encouragement. But by every technique short of that we should endeavour to ensure and hasten the death of the African vernaculars. It is important to note that no small number of Africans, especially among the more emancipated, share views of this type.

But many others, again including numerous Africans, hold the almost diametrically opposite opinion. Firstly, they do not believe that all the languages of the African primitives living under European rule will necessarily die out without an enormous amount of nursing, any more than—to take but one example out of several—all the tongues of the European barbarians did under the Roman Empire even in those parts of Europe where the hold of that empire was firmest and most prolonged. If, they argue, the Germanic languages could not only continue to live, but could actually manage to grow and flourish, in the entire absence of pampering by Rome, what really compelling reason is there to assume that our South African Bantu languages will perish unless we bolster them up at an excessive cost? Secondly, people of this school cannot agree that it would be a good thing if all our Bantu languages were to die out. They deny, on the one hand, that if our Zulu-speakers were to continue to use their own language, this would automatically prevent them from absorbing all, good and bad, that Western Civilisation in its South African variety has to offer them, any more than—to choose an example from Eastern Europe this time—the Slavic-speaking peoples were prevented, by adhering to their Slavic mother-tongues, from making their own many elements from the differing cultures with which they came into contact. On the other hand, this school of thought affirms that for a people to retain its language is to retain one of the most powerful media to their hand both for assimilating and shaping to their own needs cultural elements derived from without, and also for developing those contributions to the culture of the world at large which they and they only can make, and which well up from within. For this assertion there is, it must be admitted, strong justification in the part played by linguistic and allied cultural movements in the development of peoples living at a lower cultural level than others with whom they came into contact, and in the regeneration of those with cultures stagnant or on the decline. The great nationalist movements which have been taking place, chiefly from the mid-nineteenth century onwards, in various parts of the globe, and which have helped more than one people to achieve a greater measure of cultural and political consciousness, solidarity and emancipation than they ever attained before, or have enjoyed for a long time. have all had strong linguistic sides. One thinks, for instance, of the revival of Erse in Eire, of the vigorous new life that Hebrew is leading in Palestine; or, for examples perhaps more pertinent to our present theme, of Afrikaans in our own

country, or of the tongues of the non-Russian nationalities in the Soviet Union. The case of the latter is, indeed, remarkable on many grounds. Neglected, or actually suppressed under the Tsars, they are, under the Soviet *régime*, not only given full freedom and an acknowledged status in the constituent republic concerned, but also fostered by every technical device, at almost shock-brigade speed, so that they are fast becoming extremely important means through which a new and superior culture is being instilled into the peoples who speak them, and through which these peoples, in their turn, are making no small part of their contribution to the building-up of the new Soviet culture.

The answer which the reserved school of opinion gives to the first of our questions would seem to be the theoretical basis upon which South Africa's policy towards its Bantu languages is at present founded. It is, firstly, that these tongues are at least very likely to continue alive for some considerable time to come, though they may well need some artificial help for the purpose. Secondly, however, as to the role such languages should play in the life of the people who speak them, it is that such part must inevitably and rightly be but a modest one. In the initial stages of cultural development—and this in the case not only of Bantu-speaking communities as a whole, but even of the single individual whose mother-tongue is a Bantu language—such a language may be the only or at least the best vehicle in which the culture of the outside world can be conveyed to the African, the one or at least the most suitable means he has of developing his own cultural individuality, old and new. But it cannot serve as a completely satisfying medium for either purpose, and soon, for the individual as for the community, there must come a time when it is abandoned in favour of more or less wholesale employment of the European language. Hence, though we would not be wrong in giving some modicum of attention to the development of Bantu languages for quite modest purposes, any more than that would be a mistake. The languages would probably not respond very much to such more ambitious treatment; and even if they did, the game would hardly be worth the candle.

Before proceeding further, let me now give some indication of what are generally agreed upon as primary conditions which a Bantu language must fulfil if it is to have much chance of surviving and of playing a worthy part in the life of those who speak it as their mother-tongue. It must be, or become, an efficient, vigorous and adaptable means of expression; and it must have, or acquire, a number of speakers sufficient to make it economically practicable to produce in that language the quantity and quality of literature which it must have if it is to serve any but the most minor cultural ends. What prospects have any of our languages of meeting such requirements at present, and what steps should be taken to aid any of them to do so, if we think it right that they should be assisted to do so?

We may take the question of numbers first. We have in the Union representatives of four Bantu dialect groups, each of which groups extends into other territories. Of these, the estimates which seem to have received most general acceptance are that the largest group, the Nguni, has some 3,000,000 speakers; the Sotho group comes next with over 2,000,000; the Shangana-Tonga group has in the neighbourhood of 750,000; the smallest group, the Venda, has not many more than 150,000. The figures for even the smallest of the minor languages that have managed to survive the struggle for life elsewhere are considerably in excess of these, and even languages with much greater numbers of speakers have been known to die out, or at least to stagnate and decline. This aspect of the situation in South Africa therefore certainly does not give room for any easy optimism in the minds of people who feel that it would be a pity if all our Bantu languages were to perish. It is true that, up to the present, of all the more or less pure-blooded Bantu-speaking inhabitants of the country, only some few thousands have abandoned the use of a Bantu language entirely, and that the vast majority of Africans, including those with a very fair knowledge of a European language, continue to employ a Bantu language far more than they do a European one. But the question as to how long this state of affairs may be expected to continue relatively unchanged, while it does not as yet perhaps give cause for actual pessimism, must at least occasion serious concern. The number of persons habitually making use of a given South African Bantu language cannot, under present conditions, be expected to grow any faster than the natural increase of population in each dialect-community; it is only by some new departure in policy that we could hope to add to the number of users of any of the languages concerned, by making the number of languages in use smaller—a topic we shall discuss to some extent later. But even by so doing we should probably be able to secure to only a reduced proportion of forms of South African Bantu speech a number of speakers sufficient to give them a really fair chance of not dying out through mere lack of population.

A closer examination of the present position from this point of view reveals an even more disquieting feature. The four dialect groups mentioned are at least as far removed from each other, and as mutually unintelligible among their several speakers, as, for instance, English, Dutch, and a Scandinavian language, or even as, say, English, French, and Roumanian; but within each single dialect group, the dialects tend to be even closer to each other and mutually more intelligible among their several speakers than, say, Nederlands and Afrikaans, or Low and High German. Within each dialect-group, of course, there are degrees of similarity between the individual dialects which constitute it; and in each such group there are smaller sub-

divisions, the so-called dialect-clusters, the members of which, in combination, make up more or less distinct sub-entities within the larger whole. But within each larger group there remains, as has been indicated, an extremely high degree of mutual intelligibility between the speakers of the individual dialects, no matter to which cluster they belong. In this way, a Sotho-speaker from Bechuanaland has no serious difficulty with another from Basutoland, one from the North-Eastern Transvaal is at ease with one from the South-Eastern Orange Free State. The fact that so many of our Africans, at one time or another, spend some part of their lives in multi-dialectal areas like our larger towns, considerably develops this already existing characteristic of the dialect-groups. There are, in fact, evolving in the larger centres with more or less permanent multi-dialectal populations forms of Bantu speech from which all those marks which differentiated the individual dialects or dialect-clusters that have given rise to them are being effaced, surely and not so very slowly. Under such circumstances, each of the four groups could well be served by a single written form of it, as is the case with all the more advanced peoples, who have, for instance, but one written Spanish, though there are numerous spoken forms of that language both in European Spain and in Spanish-speaking America; one way of writing French, whatever dialectal varieties may exist among its speakers. But, owing very largely to purely fortuitous circumstances, only one of our four groups, and that the smallest, Venda, has but one written form. Nguni has three—Xhosa, Zulu, and Rhodesian Ndebele; Sotho has three—Tswana, Northern Sotho, and Southern Sotho; Shangana-Tonga has three—Central, Northern and Southern; and it should be remarked in passing that the present position in this regard is already a step away from the state of affairs that used to prevail, when divergence in orthographic practices had given Nguni, and in still greater measure Sotho, even more written forms than they possess now. The result of the creation of more than one written form for each of the groups concerned has been to split the speakers of its various dialects up into yet more dangerously small communities, and to lessen yet further the chances of survival and growth of any of the written speech-forms so created.

Let us next take up the problem of what chances any of our languages have of serving more or higher cultural needs than they are doing at present among the peoples who speak them. On this point I think we are justified in taking a rather more hopeful view than on the previous one. All the evidence known to me justifies the belief that, even before the White Man came to this country, these languages had already developed into no unworthy media of communication of thought, capable of expressing clearly, fully and even elegantly whatever the African had up to then thought of saying—and anthropologists tell us that that

was relatively neither little in quantity nor poor in quality. With the impact of Western Civilisation upon South Africa, however, two even more significant merits of these languages came to light; firstly, that they already had it in them to express, using their own resources only, a surprising amount and variety of the new culture that was being communicated to their speakers, especially in the religious sphere, and in the humanistic field generally; and secondly, that they had the amount as well as the kind of flexibility to enable them to absorb many of the semantic and idiomatic elements which the European languages had evolved for the expression of ideas foreign to Africa, and for which there was no equivalent in the African tongues. I might mention a very few examples of this quality of adaptability in our Bantu languages. In all the groups we have been considering there are now translations of the whole of the Bible; but the last of them to be without one, though it had the entire New Testament a considerable time before, only got its full Bible in the same year as the whole of that Book first saw the light in Afrikaans. In three of the groups, there are translations of the "Pilgrim's Progress;" in one, translations of a Shakespearean comedy and tragedy respectively. In at least three out of the four, there are books, translated or adapted or written specially, on grammar, on hygiene, on agriculture, on history, on geography. The quality of all these naturally varies; that of the Bible translations is high, I personally feel, on any showing; but however modest that of some of the others may be, the very existence of all of them must, I think, be regarded as sufficient proof of the contention that the languages in which it was found possible to produce them are at least not initially unsuitable or unworthy instruments for the Bantu to use in assimilating and after their own fashion transmuting European culture. Nor does the matter stop short here. Prior to the arrival of the European, there had been produced in the Bantu languages an indigenous oral folk-literature, respectable in bulk and not unimpressive in content, by way of tale and proverb, of recitative and song, in prose and in verse. Since that event, not only has the production of one type of this native literature, the so-called praise-poem, gone on, but actually there have been produced, in three of the groups, specimens of types of literature previously not found in these African languages—chiefly novels, though here and there we find a drama, a collection of essays, a volume of poetry with a verse-technique and content-orientation new to Africa. The standard of all these productions is, on the whole, modest enough, though once or twice we come upon something of larger stature, such as Mofolo's "Chaka," a historical novel which has been translated into English; or Jordan's "Ingqumbo Yeminyanya" ("The Wrath of the Ancestors"), a powerfully conceived and executed tale of the clash between old and new in Bantu life. What is, for our present purpose, important to note about such

production is, however, that while doubtless inspired by European models, and yet by no means slavish imitations of them, they show that, in addition to serving as media through which the old Bantu culture expressed itself and through which at least some of the new European culture can be brought to the Bantu-speaking peoples, these languages can also act as the channels through which the new Bantu culture can find a voice.

But though these languages have their qualities, they also have their shortcomings. The chief among these is the inadequacy of the present vocabulary and idiom for the expression of scientific and technical ideas; and there are other more or less serious defects. Even if, therefore, we may find cause for steady confidence in the ability of Bantu languages to learn to fulfil the tasks that may be required of them, there is no room for carefree belief that they have nothing or little to learn.

It would be wrong to assume, furthermore, that all of the groups, or all the speech-forms within any one group, possess the potentialities which we have just discussed. Whatever the present or possible future suitability of Venda and Shangana-Tonga may be as media of expression, I very much fear that the number of speakers these severally have now, or are likely to acquire for a very long time to come, are too far below the minimum that would make it economically practicable for these groups to develop written forms with a sufficient amount and variety of literature through which their intrinsic suitability might be developed and made effective. One may feel regret that these tongues should suffer eclipse in course of time; but, on the one hand, it would be no worse a fate than has overtaken and is overtaking numerous other vernaculars, including many with the dice much less heavily loaded against them; and on the other, abandoning Venda Shangana-Tonga to their fate may well prove to be the only feasible way of ensuring that their present speakers may have a Bantu language as their cultural medium, if that is considered to be a good thing. Two facts of importance in this connection should be borne in mind. Venda speech has close affinities with two neighbouring dialect-groups, Shona and Sotho; and the affinity with Sotho is very great indeed—Venda is much closer to Sotho than Sotho, Shangana-Tonga and Nguni are to each other. Even if there were no other contributory factor, a Venda-speaker could learn Sotho relatively easily and quickly. But there is another contributory factor—the geographical contiguity between the area occupied by Venda-speakers and certain areas occupied by Sotho-speakers. These two factors in conjunction have operated so powerfully that a not inconsiderable proportion of Venda-speakers, especially adult males, at least understands and to some extent speaks Sotho. Something similar holds, *mutatis mutandis*, in the case of Shangana-Tonga. The affinities of this form of Bantu speech with others is not so strongly marked as in the case of Venda, and what affinities there

are are more widely scattered, though even here the position is not such as to make it a matter of serious difficulty for a Shangana-Tonga speaker to learn Nguni, Sotho, or, for that matter, Venda, even in the absence of any other contributing factor. But once again there is another contributing factor—historical rather than geographical this time—which has helped to bring about the fact, important for our present purpose, that a considerable proportion of male Shangana-Tonga speakers can at least understand, and mostly also speak, Nguni. It would, accordingly, not involve serious linguistic dislocation if the Venda-speakers were, in course of time, to abandon their speech in favour of Sotho, and if the Shangana-Tonga speakers were to attach themselves in a similar way to the community of Nguni-speakers. Such a thing has taken place many a time in the linguistic history of the world, in cases similar at a least comparable. I mention only one of two examples—the Frisians in Holland, the men of Low German speech in Germany, Provençal-speakers in France, and, until recent times, the Catalans in Spain.

But it is not alone Venda and Shangana-Tonga which may have to submit to partial or total eclipse in order to make it possible for their speakers to have a Bantu-orientated linguistic future. In the remaining two groups, it might be at least highly advantageous, and in one it might prove to be imperative, for all but one of the existing written forms within each of these groups to submit to a process of linguistic self-immolation for the good of the whole. I shall consider the case of Sotho more particularly in this connection, partly because I know it best, partly because it is the more pertinent of the two. Here we have, as we have seen, three closely-similar written forms dividing between them, in fairly equal proportions, the linguistic allegiance of somewhat over 2,000,000 speakers. Apart from the danger of thus having the Sotho-speaking peoples broken up into communities of the order of size of the Shangana-Tonga linguistic group, there is the wastefulness, which on any showing can be but ill afforded, in time, energy, and material resources, involved in producing literature for three communities instead of for one, with detriment both to the quantity and the quality of the literature so produced. A change in the present state of affairs seems imperative.

What solutions could be suggested for such a case? There would appear to be a choice of but two means of encompassing the end of the present unhealthy situation; either two of the three existing written forms must leave the field alone to the third, or all three must sink their individuality in a fourth composite form. The first of these is the process by which, in Europe almost exclusively, and elsewhere in large measure, national and similar dominant languages have been evolved. In Britain, Southern English became the standard at the expense of the English dialects of the north, west and east,

with the Keltic languages going to the wall; in France, the *langue d'oc* made way for the *langue d'oïl*, after Breton had been elbowed out of the way; in Italy, the other forms of Italian speech left the field to Tuscan; in Spain, Castilian became the norm, while Aragonese, Leonese, and Valencian receded into the background. It seemed, at one time, that Southern Sotho was bidding fair to acquire in the Sotho group a position comparable to that of a European National language in relation to the non-standard dialects of the country. It had, for various reasons, managed to get a considerable start over both Tswana and Northern Sotho. It was the first to possess a uniform orthography, though an unsatisfactory one; to develop more or less standardised lexicological, morphological and syntactical norms; and to produce a literature which, though absolutely modest in quantity and quality, was in both respects well ahead of what had been evolved in the other two dialect-clusters. All these features had given Southern Sotho a prestige and a sphere of influence considerably greater than those of Tswana or Northern Sotho. But this is now considerably changed. Progress in Southern Sotho, though it has not ceased, has slowed up considerably, while Tswana and Northern Sotho, particularly the last, have developed at a much faster rate than before. Each of the latter has acquired a uniform orthography, and some measure of lexicological, morphological, and syntactical standardisation; while—again in Northern Sotho more particularly—there has been marked development in the linguistic and literary resources of the cluster. In this way the start which Southern Sotho once had over its fellows in the group has been very considerably reduced even if not yet quite wiped out, and the likelihood of the speakers of Tswana and Northern Sotho dialects abandoning the existing written forms of those dialect-clusters in favour of standard written Southern Sotho as their literary languages has been rendered correspondingly small.

It would seem, accordingly, that at this stage the only feasible solution left is the second of those indicated in this connection—the evolution of a unified form of written Sotho, analogous to the unified form of Sotho speech which, as has been indicated earlier, is evolving in our larger centres where the population contains Sotho-speakers from the several dialect-clusters. But while the spoken norms alluded to are being evolved but half-consciously, unmethodically, slowly, painfully, under unfavourable conditions, and frequently with undesirable results, it would seem possible by planned action to evolve a written standard in the full realisation of what the aim is, and working towards that aim systematically, with all possible speed, with the minimum of dislocation, under optimum technical conditions, and with some confidence that the result will not prove undesirable. Solutions of this kind have been attempted, and have met and are meeting with some measure of success, elsewhere in Africa. I mention only one of these cases, but that quite near home. In Southern Rhodesia a unified Shona, aiming

to serve the literary needs of at least the main body of Shona-speakers, and ultimately of the whole Shona community, has come into being, and seems to be slowly but surely gaining ground. If the will is there, it should be possible to attempt something similar at least for the Sotho group, and possibly also for the Nguni group, in our country.

But painful experience has shown that even the suggestion of linguistic unification is apt to arouse very mixed feelings in the breasts of many if not most of those in South Africa who habitually use one or other of the dialects that would be affected. Africans, and with them many Europeans, are markedly conservative in linguistic matters, and such a relatively new concept as linguistic unification evokes more bewilderment and dislike than understanding and sympathy among them. Again, even when such an idea has been grasped and has found some favour in theory among selected representatives of a Bantu linguistic community, it is another matter to get even such selected representatives to accept the actual practical consequences of such a notion, and quite another yet again to get a wider circle of people to either understand or sympathise with what is really involved. The first step in any such scheme of linguistic unification must be the elimination of any orthographic differences that may exist within the several groups concerned. The history of the attempts, initiated about fifteen years ago, at doing this for those of the South African Bantu dialect-groups that needed it is instructive. Again and again the basis upon which unification had any hope of being carried through in practice had to be narrowed. The Venda group was not affected; it alone had but one current orthography in which its one literary standard was written. In Shangana-Tonga, attempts to unify the Central, the Southern and the Northern dialect-clusters in respect of the orthographies of their written forms had to be abandoned, and unification of the Central and Southern only could be proceeded with. In Nguni, a considerable degree of similarity was eventually achieved between the orthographies for Xhosa and Zulu; but these orthographies are by no means identical, and Rhodesian Ndebele, the remaining Nguni dialect-cluster which had a written form, is still outside even such measure of orthographic unification as there is in this group. In Sotho, we have something similar to the Nguni case. Here, from the outset, those who officially controlled the one existing Southern Sotho orthography refused to consider any orthographic unification that would involve any change whatever in the way Southern Sotho was being written, so that no attempt at such unification upon a tripartite basis could be made. Then it was found impossible to put through one orthography to cover both Tswana and Northern Sotho; and in the end, the most it seemed practicable to aim at was to reduce the number of contending systems of spelling Tswana and Northern Sotho to one for each of these

two dialect-clusters. This object was, at that stage, achieved relatively quickly and easily for Northern Sotho; but the attainment of even this limited goal took. in the case of Tswana, another half-dozen years, and demanded a high price in effort, and in compromise with the broader interests both of Tswana alone and of the Sotho group as a whole.

I have given the above details on this single topic to show the slowness and difficulty of achieving, by the methods so far tried in this country, even the relatively meagre results attained up to the present in what are, after all, merely the first steps along the road to Bantu linguistic unification. It must be clear that any hope we have of unifying on a higher plane—of achieving a single literary medium even for each main dialect-group, not to speak of a single Bantu literary language for the whole of Bantu-speaking South Africa, will be small and will have to be long deferred if we adhere to our present orientation and techniques. Is the case hopeless, or can we see light anywhere?

I have recently come upon a fascinating account of the language-situation in the Philippines, and of the remarkable linguistic experiment which was there being conducted at least until the time of the Japanese occupation of those islands. The basic situation there appears to be fairly analogous, in several fundamental respects, to what we have in South Africa; but the method of tackling that situation is, in the boldness of its conception and in the apparent quality, amount and speed of the success it has achieved, so very different from anything we have to show in our country, that I think we would do well to study the Philippine scene with a view to deriving from it both some hope as to what it may perhaps be possible to do here and some inspiration as to ways and means to be adopted of doing it. The following sketch is based, and some of the phraseology in which it is conceived is derived, from a chapter entitled "Wanted: A national language," in the book called "The Philippines: A Study in National Development," by Joseph R. Hayden, published by Macmillan in New York in 1942. Dr. Hayden was vice-governor of the Philippines from 1933 to 1935.

Upwards of ninety distinguishable forms of indigenous speech, we learn, are current in the islands; but though distinguishable, they are closely related to each other, and appear to shade off into each other much as do the dialects of one of our South African Bantu dialect-groups, though here and there it may be that the relationships between certain Philippine dialects or dialect-clusters is no greater than that between our Bantu dialect-groups in relation to each other. As with us, some dialect communities have considerably greater numbers of speakers than others, and the written languages which have been created in them have developed to a greater extent than those of their smaller fellows. Of the total population of about 16,000,000, nearly ninety per cent. speak dialects belonging to one or other of

the eight or nine principal dialect-clusters, or, as they are called in Dr. Hayden's book, languages. The Philippine peoples were only just emerging from centuries of dominance by alien rulers when Japanese sway descended upon them; and the result had been that even before this latest subjection two foreign languages, Spanish and English, had come to occupy in the Philippines positions at least comparable to those of Afrikaans and English in South Africa. The same divergent answers that we have met in South Africa have been given by various schools of opinion about the possibility and the desirability of any of the Philippine languages having a future, and very similar arguments have been employed there to support one school or to attack another. Till quite recently, the resultant of these answers in the Philippines has been very much like the resultant we have noted in our own country; reserve and doubt in theory, coupled with insufficient and hesitant action in practice. It seemed, indeed, as if the Philippine languages were destined to die out, or at best to drag on but a feeble existence. Numerous Filipinos were to be found in the ranks of those who felt that it was both inevitable and right that they should do so.

But as elsewhere, so too in the Philippines, the growth of national as opposed to tribal consciousness, the desire for and the striving towards political emancipation, brought with them a realisation of the part that a national language can and should play in all such movements, and a wish for such a language. This is the first really serious difference between the situation in those islands and that in Africa; but it is, of course, a fundamental one. Bound up with it is the great lesson that must be learnt by those Africans and their European friends who hope for African political emancipation and cultural progress—that they must profit by the example of other times and other places in this regard, and realise the value, for both the objects they have in mind, of African equivalents for the national languages that have done so much to attain those objects for other people.

The second serious difference between the Philippines and South Africa consists in the technique that has been adopted to bring about the desired result. Firstly, it was laid down in the Philippine Constitution that (I quote verbatim) "the National Assembly shall take steps towards the development and adoption of a common language based on one of the existing native languages;" and obeying this mandate, the government of the Commonwealth in due course initiated a procedure intended to create such a language. The chief agency to this end was the Institute of National Language, with a director, seven members, and an executive secretary, between them representing the nine main dialect-groups. The statutes creating this institute prescribed in considerable detail the various steps to be taken and the procedures to be followed by it, and in particular fixed a time-table to be adhered to in working towards the goal set. Preliminary studies were to be made of Philippine dialects in

general, for the purpose of choosing that native tongue which was to be used for the evolution of the national language to be adopted; not later than a year thereafter, the Institute was to publish the results of such studies, and declare which of the existing tongues it had chosen for the particular purpose in hand; and the President of the Commonwealth was directed forthwith to proclaim the chosen tongue as the national language, effective two years thereafter—by which time the Institute was to publish a standardised dictionary and grammar of it. The programme thus prescribed has been followed with precision and despatch. In November, 1937, the Institute recommended the adoption of Tagalog, numerically and perhaps otherwise the most powerful of the main written languages, as the basis for the national tongue; and that language was duly so proclaimed by the President before that year was out. By June, 1940—the prescribed dictionary and grammar being then available—this national language came into operation in all the Philippine schools; and by 4th July, 1946, it is to be, together with English and Spanish, an official language in the islands.

Thus in a remarkably short space of time the Philippine people have laid the foundations of a native national language. To be sure, they are only the foundations, for the language chosen is as yet no more than a comparatively rudimentary instrument which the people must learn to use, and which they will have to experiment with and develop before it renders them the fullest service of which it is capable. But that every section of the people should have pledged themselves to use it is a remarkable and heartening proof of their political sagacity. Even more remarkable is the smoothness of the process by which this result was brought about—a result which, competent opinion in the islands holds, would not have been possible as recently as a decade ago. Dr. Hayden sees the reason for this smoothness of working in several factors, each coming under the broad heading of sound leadership. The President, H. E. Manuel E. Quezón, himself took the initiative, by pointing out, in a message to the first National Assembly, the course to be taken; regional or factional opposition to such a course was prevented by the creation of a carefully thought-out procedure which was understood and accepted by the people as a non-political measure; and the carrying out of the details was entrusted to a body of public men of integrity and authority, respected on all sides.

The Philippine experiment has shown that linguistic unification on an enormous scale is possible in a short time and can be achieved with an amazing degree of smoothness. Can such an experiment be repeated in South Africa? The question is a challenge to those Africans and to those of their European friends who believe that at least some African languages can and should have a worthy future.

South African Journal of Science, *Vol. XLII, pp. 84-99, June, 1946.*

THE EMPLOYMENT OF THE PARTIALLY DISABLED CONSIDERED AS A SOCIAL POLICY

BY

A. J. Limebeer.

Presidential Address to Section F of the South African Association for the Advancement of Science.

Read 2nd July, 1945.

The problems of social welfare receive more attention in the later stages of a great war than at other times, because the object of fighting a war is social—to bring about some desired object, or to resist some feared disaster of a social or economic nature. In war time also, the collective opinion of the nation and the minds of its individual citizens turn more actively to such problems; the thoughts of the public are more readily concerned with matters of gravity, especially those involving suffering; moreover, the high rate of expenditure associated with the conduct of war leads the population as a whole to become optimistic in regard to the economic possibilities of plans to improve the national lot—perhaps unduly so.

It cannot be too often insisted that the most serious difficulty in the whole matter is the economic difficulty of the provision, not of the distribution, of the goods and services with which to improve the condition of the under-privileged. The defenders of most plans for social welfare find themselves in the dialectical difficulty that if the remedies were possible the disease would not exist. It may be useful to note, at this point, a suggestion that conditions of scarcity are not due to political policy—the complexion or incapacity of the Government of the day—or to the iniquities of this class or that, so much as to the general limitations of humanity. The consideration of social problems has always been seriously obscured by politically-minded protagonists whose arguments imply that all their friends have all the virtues and all their opponents have all the shortcomings. These statements are platitudes, but day by day the newspapers reveal the necessity for their reiteration.

Consideration of the problems comprehended under the term " social security " is frequently based on certain assumptions which it would be an advantage to examine. The most important of these is that there is some natural, permanent, or fixed standard below which it is improper for members of the human race to live, or that there are some misfortunes to which they should not be exposed. The standard is normally fixed in the minds of commentators by empirical judgments

based on current opinion. In fact, the effectual fixing of the standard depends entirely on the resources available. Standards change and improve; but improvement, although we think it usual, is not invariable. There is a grave possibility that the destruction of the means of production during the war may in some areas forbid progress for many years. By current standards we have improved on former methods because, apart from other reasons, we can afford to do so; but, nevertheless, our activities should be based on the assumption that whatever we do is a step on the road, and not the reaching of a destination. A standard which takes a just and accurate account of the conditions of to-day would have been impossible yesterday and may well be regarded as inadequate to-morrow. Progressive improvement of the general standard of life and a steady growth of the proportion of people enjoying the full amenities of life (as currently assessed) is a normal, proper and practicable object. Proceeding with our examination of definitions and ideas, we can, I think, add a rider to our expressed ambition to improve the general standard of life, and say that it should also be our ambition to reduce the dispersion of standards of life, provided that we bring this about by the improvement in the lot of poorer people and so raise the general average.

In general consideration of the aims of social service, the benefits proposed are not infrequently considered collectively, without regard to a somewhat important distinction in their nature. The Social Security Committee defined a social security scheme as the provision of benefits:

"(a) to individuals not gainfully occupied because they are too young, too old, temporarily disabled, permanently disabled, or for other causes not due to their volition;

(b) to individuals gainfully occupied but unable to maintain themselves and their dependants at levels to be determined;

(c) in certain circumstances to needy mothers with young children, as it is undesirable that they be gainfully occupied;

(d) in respect of injury or disease sustained in employment; and

(e) to assist in meeting the costs of births and funerals."

The provision of benefits to the young, the temporarily disabled, the unemployed, and to pregnant or nursing mothers is, if effectively applied, temporary and wholly constructive. Maintenance of the old, or of the totally disabled, and assistance in connection with the cost of funerals is provided as a matter of sentiment or public duty, without any expected or possible return.

It may be remarked that, so far as the Gold Mining Industry is concerned, most of the general services are in existence under the aegis of the Mines Benefit Society, the Witwatersrand Gold Mines Employees' Provident Fund, the

Rand Mutual Assurance Company, Limited, and the Miners' Phthisis Board. The integration of these existing services with the Government plans will be a practical difficulty of some magnitude, owing to the fact that at many points the existing provision exceeds that which would be possible in a national plan.

Whilst we comment on the Committee's programme, it should be noted that assistance to Class (b) (individuals gainfully occupied but unable to maintain themselves and their dependants at levels to be determined) should, properly speaking, be constructive, but all too often it proves in practice to be otherwise. This classification of the recipients of benefits is of importance inasmuch as the temporary and constructive benefit contributes indirectly and sometimes directly to the national income, whereas the second class of benefit is unremunerative. Insistence on the economic factor appears to incur charges of callousness or to be regarded as indicating an attitude of lukewarmness to the whole matter, but it must not be overlooked that there are only two fundamental problems in the social welfare of any community—the production of the means of welfare—food, clothing, shelter, health, education, recreation, etc., and the allocation of the totals amongst the population. The use of money as a measure is merely the employment of an instrument.

Casual references to the problems of poverty all too often assume, or at least imply, that they could be settled by a transfer of resources from those vaguely referred to as "the rich." The Social and Economic Planning Council stated, however, in a passage opening in paragraph 26 of its Second Report and speaking of the financial requirements, that "if in the period between 1938 and 1955 the Union found it impossible to raise the average income per head, direct taxes varying from an average of 20 per cent. on incomes of £300 per annum up to 70 per cent. on incomes of £20,000 would be needed." Under normal peace-time conditions this rate of taxation on large incomes would, of course, severely restrict the amount of capital available for new industry, whilst such a rate of levy would be almost intolerable for the lower income groups. The Council itself acknowledges that direct taxes on this scale would not be feasible. In Britain, a far wealthier country, the same criticisms have arisen. These considerations are primary to our problem, as they demonstrate that, in this country and at the present time, the insufficiency of the total supply of the means of welfare and comfort, rather than the ill-distribution of that supply, is the condition calling for remedy.

Having reached this opinion, the most inviting object of attack is the low standard of production and poor condition of welfare of the less effective producers. Perhaps we may pause at this point to reflect that the problem with which we are dealing is not a new one. We are discussing an age-old

problem with a degree of perception which has recently achieved some increase, but we are using a few new phrases. We cannot ignore, though we need not be discouraged by, the warning that we always have the poor with us.

The general effectiveness of attack on the problem of the employment of sub-standard persons is likely to be greatly improved by suitable classification, and by devoting special attention to the more promising types. As a question of principle, this classification need not be based on the origin of the deficiency. A limb lost in industry or in a street accident is missed as much as one lost in war. One main division for our purpose is into physical deficiency and psychological deficiency—the latter class including the idle and incompetent and many drunkards. It may be said at once that far less progress has been made in that part of the field.

One of the easiest and most useful approaches to the employment of sub-standard persons is by means of special steps to employ those who have previously been efficient members of the community, but who have suffered illness or injury. In almost all cases, such persons are willing and anxious to help themselves. The employment in suitable occupations of the physically handicapped is of as much economic importance to the State as to the individuals concerned, inasmuch as the number of gainfully occupied persons is increased. So far as individuals are concerned, not only does their economic position become better than could normally be provided if they are not gainfully occupied, but the psychological benefits are even more important. The feeling that they are able to maintain themselves results in the maintenance of self-respect, happiness and general health. They, of all people, are willing to admit the truth of a statement in a recent American study that "true social security needs work as a right, and regards retirement as a hard necessity, and warns men that life is a struggle and desertion from that struggle cowardly." One of the most noticeable characteristics of, let us say, crippled children, is their desperate wish to be like others, and one of the surprises in dealing with them is that they fairly often succeed in far greater measure than one would think possible. The increase in the scope of employment of sub-standard persons is one of the few important benefits resulting from the two great wars. During war-time the shortage of man-power leads to special consideration of the possibilities of increasing the number of producers, especially by promoting employment of, and production by, persons unfit for active military service.

Under post-war conditions the solution of the problem must be considered in the light of the burden on the national finances created by the maintenance of non-producing elements, and in many parts of Europe this will be a problem of great magnitude. After the last war, several countries imposed on employers the duty of employing a certain proportion of persons of sub-standard capacity. A typical proportion was of

the order of 2 per cent. of the totals employed in large undertakings.

Up to date attention has been devoted to this matter with varying degrees of success, but in rather a piecemeal fashion in different countries and by individual industries. Many of you will, no doubt, be acquainted with the principles of such schemes as applied in major industries throughout the world. In South Africa less progress has been made, but that is not necessarily a reflection on the industries of the country. Special arrangements for the employment of sub-standard individuals are most easily made in industries employing large amounts of automatic plant and many routine processes. Plant can, if necessary, be designed in a large factory to accommodate workers who lack the use of certain limbs. Various types of sub-standard persons, including the blind, can be employed in sorting parts resulting from dismantling processes.

In South Africa industries which could contemplate work on lines followed with success elsewhere are not, as yet, established on a sufficiently large scale. On account of the nature of their activities, the two largest engineering industries, the gold mines and the railways, do not have a large proportion of work of a suitable nature. The position in this country is, therefore, that we have to investigate the problem as it presents itself to us. Study of the work which has been done elsewhere is essential if we are to handle the problem without waste of effort, but precedents established in industries with characteristics entirely different from our own are not likely to provide us in all cases with guides useful in detail.

An important step in the investigation conducted by the Gold Mining Industry arose from an enquiry in October, 1942, by the Interdepartmental Committee on Deviate Children. It was not clear at first sight why the Mining Industry should have been approached in connection with this matter, but an explanation was obtained from the responsible Department (that of Education) that the Government had under consideration the possibility of preparing and developing formal plans for the education of afflicted and sub-standard persons and for their subsequent employment. The Gold Mining Industry, therefore, was approached as a large-scale employer of labour. In the replying memorandum the view was expressed that the solution of the problem of employing persons of impaired faculties would not be best dealt with by provision under various headings, dependent on the origin of their respective deficiencies. From the point of view of the public administration, some division is probably inevitable, but for the solution of the problem there is no advantage in a system under which the congenitally sub-standard and the sick are dealt with by the Department of Social Welfare; those injured in industry by the Department of Labour, and those injured in war by the

Department of Defence. Insofar as division of authority is inevitable, close co-operation would appear to be highly essential. The wide scope of the Department of Demobilisation and Social Welfare recognises this.

In course of the general consideration of the problem initiated by the enquiry to which I have referred, the investigators on behalf of the Mining Industry arrived at the point of giving their attention to a special aspect of the problem, namely, rehabilitation. As has already been stated, one of the main bases of division of the various classes of social service is according to productivity or non-productivity. In other words, does the State or the community receive anything in exchange for the assistance extended? In this connection it appeared to the mining investigators that a useful field of enquiry would be the rehabilitation and employment of the disabled, interpreting that term in its widest sense and without special reference to the origin of the disablement. If such employment could be achieved, or unemployment prevented, it would mean that a certain proportion of the expenditure involved in conducting a scheme of social service would be transferred from the non-productive to the productive classification.

The successful employment of disabled persons on a large scale may require some change in outlook as regards the placing of men in jobs. In the past jobs have been differentiated almost entirely on the basis of the training and experience necessary. If the problem be considered from the point of view of placing in gainful occupation every individual capable of being so placed, revolutionary changes will be brought about in the economic condition of many sub-standard individuals. In ordinary circumstances it rests with the seeker for employment to select and apply for employment and after appointment to satisfy the employer in the performance of duty in the post. It is rightly felt that it is the concern of the normal individual to adjust himself to the economic and social requirements of the State and of the society in which he lives. To a great extent those unable to fulfil these requirements, and having no claim on any large organised industry, have hitherto found themselves under severe economic disadvantage. Whatever our proposed remedy, we are all of the opinion that this is neither acceptable nor inevitable.

In the experience of the Gold Mining Industry it is possible to employ a large proportion of the victims of illness and accident. The concern of the Industry in the matter originated from, and has been influenced by, the desire of the controllers of the Industry to employ, where possible, persons who have lost health or who have been injured in the Industry. The success which has been achieved, over many years, is due to the large scale of the Industry and to the fact that many of its officials are acquainted with the study which has been given to the matter. The experience has, of course, been con-

fined almost entirely to the problem of employing mentally normal individuals who have suffered physical impairment in the service of the Industry. On consideration of the reply to the enquiry of the Interdepartmental Committee, and associating the arguments used with the problems to be expected after the war, it was decided to summarise the existing records with a view to investigating the possibility of developing work of which the mines probably have better experience than any other branch of South African activity. It was felt that if the study of the problem could ultimately be carried to the point of endeavouring to develop specific arrangements for the normal employment of persons of sub-standard faculties, a much wider range of employment might be made available. Instead of so much concern with finding employment for, say, an individual man with one leg, better social and economic results might be attained from an approach on the lines that a machine with one treadle can be worked by a man with one leg. In other words, instead of seeking to place individual defectives, a move might be made in the direction of so organising industry that jobs would be brought within the general capacity of defectives in need of employment. It is along these lines that employers can make their most effective contribution to the problem. It has already been mentioned that in some countries the point is covered by legislation.

Apart from the difficulty created by the lack of routine work on the surface of the mines, there is a further difficulty inherent in mining, namely, that much of the most important work is underground and that most underground work can normally be carried out only by men in full possession of their limbs and faculties. Apart from the nature of the work, which calls for physical fitness, not many sub-standard persons would be suitable to meet the general conditions underground. On the other hand the principal requirements for a substantial proportion of the work underground are physical health and ordinary general intelligence, whereas surface employment in the offices and workshops usually calls for a better standard of education and some specific training. The provision of surface employment for disabled underground workers is not, therefore, an easy problem. A special matter for consideration is the employment of underground workers almost invariably of middle age, who are certified in the early stages of silicosis. It is rightly felt that these men have a prior claim on surface employment suitable to their abilities.

At the outset of the work, in 1943, a survey was carried out to ascertain the number of partly disabled persons employed on the mines. The disabilities were divided into four categories:

Category 1.—Loss of limb or fingers.

Category 2.—Loss of sight of one or both eyes.

Category 3.—Loss of hearing.

Category 4.—Miscellaneous.

The following data relate to Europeans, of whom some 40,000 were employed at the time of enquiry:

Category 1.—There were in service 213 men who had lost one or more limbs. The disability resulted from

Mine accidents in just under 50 per cent of the cases (105),

Road or rail accidents in about 25 per cent. of the cases (51),

Military service in about 15 per cent. of the cases (32). and from other causes in the remaining 25 cases.

It is not possible in the time available to give details of the various occupations in which these men were employed. It is possible to mention but a few. One man who last both hands in a blasting accident was employed in charge of a gang of natives. Two men each lost both legs (one lost his right arm as well) as a result of railway accidents. One was a clerk and the other a telephone operator. Another lost his right arm and a leg, he was a clerk. Yet another lost his left arm and a leg, and was still employed as a shaft timberman.

The last mentioned case is proof that a man can continue in an arduous occupation if he has the necessary courage and determination to overcome his disability. That others have shown similar courage and determination is evidenced by the fact that of 117 men who had been employed underground prior to the loss of a limb at least 55 per cent. were still so employed.

Where the accidents arose out of employment (whether on the mines or elsewhere) employees had, of course, received compensation in terms of the Workmen's Compensation Act. This was not taken into account in determining the wages of disabled employees when engaging them. They were all employed at standard rates of pay. A comparison of the present earnings (apart from compensation) of these employees with their earnings prior to sustaining the disabilities showed that 66 per cent. had suffered no loss of earning power, 8 per cent. had suffered less than 10 per cent. loss in earning power, and only 26 per cent. had suffered a reduction of earnings of 10 per cent. or over.

Category 2.—At the time of the survey twelve blind men were employed as telephone operators. Of these, six had lost their sight as a result of mine accidents. The number so employed to-day is fifteen, and it is hoped to increase this figure materially.

Special arrangements have been made on one of the mines for the training of blind men as telephone switchboard operators. The training is done by a man who himself was blinded in a mine accident. The Postmaster-General has informed the Chamber of Mines that his Department would substitute shutter type switchboards for light indicator type boards, free of charge, if the renter undertakes to employ a blind operator. Europeans

in employ lacking the sight of one eye numbered 217, of whom 88 per cent. had suffered no loss of earning power. Of these, just under two-thirds had lost the eye as a result of a mine accident.

Category 3.—There were 13 totally deaf employees engaged in various occupations on the surface and underground. Only three of these lost their hearing as a result of mine employment.

There were also five employees who had been deaf and dumb since birth. One was a clerk, two were mechanics and two were carpenters.

Category 4.—There were a number of employees suffering from disabilities due to sickness. deformities, and, in varying degrees, loss of function of limbs. It is not possible to enumerate all these.

It is of interest to note, however, that the number of silicotics in employment was 1,460, of whom 297 had advanced beyond the primary stage and could be considered as at least 50 per cent. disabled.

If, in regard to silicotics, it is assumed that a stage of silicosis beyond the primary stage represents a degree of disablement of 50 per cent. or over, and in regard to other disabilities the rating used for the purpose of the War Pensions Act is applied, it is found that the number in service with a degree of disablement of 50 per cent. or over was at least 757, as follows:

Loss of two or more limbs ...	5	100%	disability
Loss of right arm above the elbow	18	70%	,,
Loss of right arm below or of left arm above elbow	26	60%	,,
Loss of one leg above the knee ...	73	60%	,,
Other cases of loss of limb ...	91	50%	,,
Loss of sight of both eyes	12	100%	,,
Loss of sight of one eye	217	50%	,,
Deaf or deaf and dumb	18	80%	,,
Tuberculosis and/or silicosis beyond the primary stage ...	297	50%	,,
	757		

This represents 1·9 per cent. of the number in service at the time of the investigation.

An examination of the number of disabled natives in employment revealed a much smaller proportion. It must be remembered that natives do not, as a rule, make mining a career. The majority of natives who have suffered a serious disability return, after compensation, to the territories from which they were recruited, and only a few attempt to return to the Industry. Where a native, who has been disabled as a result of mine employment, desires to return, every effort is made to give him suitable employment.

Category 1 (Natives).—There were in service 946 natives who had suffered loss of limbs or fingers. Of these, 406 had a disability of 50 per cent. or over (using the War Pensions Act rating), 151 had a disability of between 30 per cent. and 40 per cent., and 389 were rated as 20 per cent. disabled or under. They were employed mainly on the surface and, in addition to receiving free food, accommodation and medical attention, earned the standard rates for their work.

Category 2 (Natives).—One totally blind native was employed on oiling shin-guard straps. The number who had lost the sight of one eye was 321. In about 50 per cent. of cases the loss was due to mine accidents. and in about one-third of the cases it was due to fights with sticks and stones.

Category 3 (Natives).—There were eighteen totally deaf and dumb, and six totally deaf natives in service.

Category 4 (Natives).—Of 209 natives suffering from deformities or loss of function of limbs, 190 were employed on the surface. There were also employed:

205 handicapped as a result of old fractures.
13 were epileptics.
7 had hernias.

All natives are employed at standard wages.

The particulars which have been given indicate the extent to which the Gold Mining Industry has been successful in employing those impaired, for the most part but not exclusively, in its own service. It will be observed that the proportion of Europeans is approximately 2 per cent. of the average number in service at the time of the investigation. This figure is, as has been mentioned, comparable with the figure provided by legislation in some of those countries which have dealt with the matter. The general extension of work of this nature would presumably be best dealt with as a matter of State policy, as small scale employers and industries inevitably lack the opportunity and may lack the skill and experience to interest themselves independently in a general programme. It would appear to be desirable that the aim should be that employment of this nature should be on an economic basis at full ordinary wages in all possible cases. If the relative problems are tackled with enterprise and sympathy, much could be done in this direction without exposing industry or the State to financial loss or the employees concerned to the acceptance of charity. The employer should have the unfettered right of individual selection, whether or not employers are required to employ a certain proportion or number of defectives. The extent to which certain types of defectives could be employed would appear to be a matter for investigation by practical industrialists.

It may, perhaps. be useful at this stage to summarise the views so far expressed:

1. The problem of employing defectives should, in the first case. be considered as a whole; division of the

programme to provide for congenital defectives, industrial injuries, military casualties, etc., should be a second stage.

2. The angle of approach to the problem should be the making of arrangements in Industry which would facilitate the employment, at the ordinary economic wages customary in the respective jobs, of any defective individuals who could perform satisfactorily the duties of selected jobs.
3. The employment of defectives should not be subsidised. Employers should, in all cases, retain the right of individual selection of employees.
4. It should be a primary object of any organisation which may be established, and also of individual employers, to see, as far as possible, that defectives are not subject to any economic or social distinction of favour or disfavour compared with their workfellows.

There is ground for hoping that attention to this problem should bring to defectives themselves important economic and psychological results, and to the State the advantage of production from persons who would otherwise have to be maintained, or partly maintained, on a charitable basis.

At the opening of this address reference was made to the fact that the general problems of social welfare tend to come more closely under review in war-time than at other times. Whilst many of the problems of rehabilitating returned soldiers and otherwise of dealing with the human problems resulting from the war are exactly comparable with many which occur in peace time, there are, of course, larger numbers to be dealt with, and great calls will, therefore, have to be met both by the State and by Industry. It is presumably accepted as clear that the wholly incapacitated are the proper charge on the State. It is possible, however, that energetic and skilful attention to the possibilities of employment may reduce the numbers that have finally to be classified as wholly incapacitated The great majority of those who have suffered some impairment as a result of military service will remain employable, and it will be the function of Industry to employ them. It appears probable that the ranks of ex-servicemen will include an important proportion of cases whose deficiencies are mainly psychological, and the problem of dealing with these will present many severe difficulties. Such cases are inherently more difficult to deal with than those of physical impairment and again, the degree of experience in dealing with them is far less.

For the purpose of arriving at some preliminary estimate of the nature and magnitude of the problem, the mines have established arrangements for the examination, by a specially appointed Medical Officer working under the Advisory Com-

mittee on Social Services, of all ex-service employees who, on medical examination prior to release or discharge, are placed in lower medical categories than on attestation. Some 9,000 men from the mines joined the various services, and some 1,900 have already returned. Of those that have returned, 778 cases are in lower medical categories and have, therefore, been examined. A smaller proportion of lowered categories may, of course, be expected in the whole number, as many have been discharged on medical grounds.

The medical categories on attestation and on medical examination prior to release or discharge were as follows:

Category on Attestation.	Examination.	No. of Cases.
A	E	452
A	C	246
A	B	9
B	E	39
B	C	10
C	E	22
		778

The cases were divided into two classes, namely those with service outside the Union, totalling 487; and those with no service outside the Union, totalling 291.

A complete table of the results of examination will be appended to this paper as published, but I will give here the final results, classified by type, with percentages:

Disability.	No.	Per cent. of Total.	
1. Disease of the respiratory system ...	84	10·8	
2. Diseases of digestive system	107	13·8	
(2 (a) Ulcers)	(72)	(9·3)	
(2 (b) Other digestive system diseases)	(35)	(4·5)	
3. Diseases of circulatory system . ..	43	5·5	
4. Mental disorders	154	19·8	
(4 (a) Psychoneurosis)	(116)	(14·9)	
(4 (b) Other mental disorders) ..	(38)	(4·9)	
5. Diseases of nervous system	51	6·5	26·3
(5 (a) Epilepsy)	(19)	(2·4)	
(5 (b) Other diseases of nervous system	(32)	(4·1)	
6. Rheumatism group	60	7·7	
7. Battle injuries	41	5·3	
8. Injuries, other than battle injuries, sustained while on active service	49	6·3	
9. Pre-existing deformities or injuries ..	74	9·5	
10. Miscellaneous	115	14·8	
Totals	778	100·0	

It will be noted that various kinds of mental and nervous disorders, chiefly psychoneurosis, account for more than a quarter of the whole In this case it is found, as would be expected, that the proportion amongst these individuals having service outside the Union is approximately twice the proportion amongst those who had no such service. It may, perhaps, attract some attention that in so small a sample, sixty-one cases having no service outside the Union were found, on discharge, to be affected by some form of mental disorder. It is also worthy of notice that battle injuries accounted for only forty-one of the 778, and that other injuries sustained while on active service accounted for forty-nine.

The Medical Officer was requested to report whether, at the time of examination, he considered the volunteer fit to resume his pre-enlistment occupation. Of the 487 having service outside the Union, 389 were listed as fit to resume their pre-enlistment occupations, and 98 were less than fit. Of those with no service outside the Union 223 were fit to resume pre-enlistment occupations, and sixty-eight were not so. It will be noted that the latter proportion is higher, a fact which appears to be an indication of the presence in the forces of men who probably should not have been there.

A further basis of classification of individuals in our sample was according to whether they undertook military service with or without permission; that is to say, whether or not they were formally released by their mining employers and granted allowances during their absence. Of the 778 of these lowered category cases 453 were so released, and 325 resigned their employment. Of the 453, 415 returned to mine employment, in occupations the same as or similar to pre-enlistment occupation. Twenty-seven returned to work substantially lighter, and four were unfit and received provident fund benefits on discharge. As to the remaining seven no information is available

Of the 325 who left without permission 246 returned to occupations the same as or similar to their former occupations twenty-five returned to lighter employment. and nineteen were paid provident fund benefits as unfit for service and were discharged. Thirty-five failed to return for reasons unknown.

Of the total sample of 778, 85 per cent. returned to their pre-enlistment occupations, 92 per cent. in all returned to mine employment.

It will be seen that as this analysis develops with the growth of the sample, the Industry will be provided with a complete measure of the problem as it affects its own employees. Naturally this investigation has not been in progress for very long, but it is assumed that in due course it will provide a valuable adjunct to the arrangements prepared by the Industry to see that its employees are not discharged from service until they are fit to resume their employment, or alternatively, until

some suitable occupation can be found for them. Arrangements are under consideration for periodical extensions of analyses similar to the present, in order to enable the controllers of the Industry to assess the progress of individual ex-service employees, and also to provide information as to the general progress of the problem as such—in other words, to assess whether or not the Industry's methods are meeting with success.

It would be of interest if it were considered possible for some similar system of record to be established on a national basis, even if it were operated locally. Officials of the Mining Industry who have worked on the problems associated with ex-servicemen have not, so far as is known, seen any similar analysis.

I have now recounted in outline, in the brief time available under present conditions of meeting, certain ideas and facts so far assembled in the largest organised Industry in the country. The work that has been done in South Africa does not compare in range or completeness with the work carried out in many parts of the world, but as has already been mentioned, that is solely by reason of lack of suitable scope. It is to be hoped that as South African industries develop, the development of the care of the partially disabled will keep step. There will, of course, be certain difficulties; for instance, many of those under reference are at a disadvantage in moving about, particularly in travelling on public transport at business hours, but these are secondary difficulties and should not be allowed to weigh against the immense value to the disabled themselves, and to the State, of placing them in employment. Still less should such difficulties be accepted as an excuse for not employing the partially disabled on the most productive work of which they are capable.

It has already been indicated that the results arrived at in the past by the Mining Industry from the consideration of this problem have, for the most part, been reached empirically. The Industry has always recognised a duty to assist those injured or otherwise impaired in its service, and for many years the officials of the Rand Mutual Assurance Company, Limited, which was originally established more than fifty years ago, have given special attention to the matter. Latterly, that attention has been intensified. Recently, as I have mentioned, one of the starting points for our present work was the enquiry from the Government in connection with the education and subsequent employment of deviate children. From that point the Industry's arrangements progressed to the setting up of a special Advisory Committee on Social Services, under the chairmanship of a member of the Gold Producers' Committee, and with a membership of officials selected for experience of, or interest in, the problems to be considered. Such a Committee is necessarily a type of research station in our present state of knowledge. It is hoped that

the functions of the Committee established by the Mining Industry will ultimately embrace a wide range of questions dealing with many aspects of the welfare of employees. The information embodied in this paper concerns only one aspect of the work, and that aspect was selected as being one of major and immediate importance.

In industry in other parts of the world it has for many years been suspected, and is now fully realised, that to consider the problem of partial disablement solely from the point of view of financial compensation is not only wasteful from the point of view of the State, but also neglects the highest interests of the victims. A certain number of congenitally sub-standard persons must always be, whilst inasmuch as progress in industry involves new processes and greater speed of movement, a certain number of industrial injuries will always occur, in spite of expert efforts to avoid them. To consider that we have fulfilled our obligations towards the victims when we provide monetary relief or have paid them the compensation provided by law is to hold a most unenterprising view. Monetary compensation is, of course, essential, but it does not solve the problem of associating the injured persons with the normal lives of their fellows. Indeed, it has the reverse effect. The victims themselves would be incomparably better pleased with co-operation. Studies essential to the development of South African industry will be incomplete if they do not find means of employing every possible individual for his own good, and for that of the State.

In conclusion, it should be mentioned that thanks are due to the Gold Producers' Committee of the Transvaal Chamber of Mines for permission to use statistics drawn from Mining Industry experience, and to Mr. G. Carleton Jones, Chairman of the Advisory Committee on Social Services.

CLASS.	SERVICE OUTSIDE UNION.				NO SERVICE OUTSIDE UNION.				ALL CLASSES.		
SUB-CLASS.	A.S.W.P.	A.S.W.O.P.	TOTAL.		A.S.W.P.	A.S.W.O.P.	TOTAL.				
DISABILITY	No.	No.	No.	%	No.	No.	No.	%	No.	% of Total.	
1. Diseases of respiratory system ...	28	21	19	10·1	16	19	35	12·0	84	10·8	
2. Diseases of digestive system ...	49	15	61	13·1	21	22	43	14·8	107	13·8	
(2 (a)—ulcers	(30)	(12)	(42)	(8·6)	(14)	(16)	(30)	(10·3)	(72)	(9·3)	
(2 (b)—other digestive system diseases)	(19)	(3)	(22)	(4·5)	(7)	(6)	(13)	(4·5)	(35)	(4·5)	
3. Diseases of circulatory system ...	19	6	25	5·1	7	11	18	6·2	43	5·5	
4. Mental disorders	68	43	111	22·8	13	30	43	14·8	154	19·8	
(4 (a)—psychoneurosis)	(56)	(32)	(88)	(18·1)	(8)	(20)	(28)	(9·6)	(116)	(14·9)	
(4 (b)—other mental disorders) ...	(12)	(11)	(23)	(4·7)	(5)	(10)	(15)	(5·2)	(38)	(4·9)	
5. Diseases of nervous system	21	12	33	6·8	7	11	18	6·2	51	6·5	26·3
(5 (a)—epilepsy)	(7)	(6)	(13)	(2·7)	(1)	(5)	(6)	(2·1)	(19)	(2·4)	
(5 (b)—other diseases of nervous system)	(14)	(6)	(20)	(4·1)	(6)	(6)	(12)	(4·1)	(32)	(4·1)	
6. Diseases of genito-urinary system ...	8	3	11	2·3	2	1	3	1·0	14	1·8	
7. Rheumatism group	15	12	27	5·5	13	20	33	11·3	60	7·7	
8. Battle injuries	39	2	41	8·4	—	—	—		41	5·3	
9. Injuries other than battle injuries, sustained while on active service ...	15	14	29	6·0	9	11	20	6·9	49	6·3	
10. Pre-existing deformities or injuries	31	12	43	8·8	12	19	31	10·6	74	9·5	
11. Miscellaneous	36	18	51	11·1	24	23	47	16·2	101	13·0	
TOTALS	329	158	487	100·0	124	167	291	100·0	778	100·0	

A.S.W.P. denotes Active Service **with** Permission. A.S.W.O.P. denotes Active Service **without** Permission.

THE BUILDING OF EARTH DAMS WITH PARTICULAR REFERENCE TO FLOOD CONTROL AND WATER CONSERVATION

BY

W. S. F. CAMERON.

Read 2nd July, 1945.

IMPROVEMENTS IN BRICKS AND MORTAR

BY

CLYDE FERGUSON.

Read 2nd July, 1945.

OBSERVATIONS ON THE WEATHERING OF GRANITE

BY

V. L. BOSAZZA.

Read 3rd July, 1945.

THE USE OF FOOTPRINTS FOR THE DIAGNOSIS OF FOOT-IMBALANCES

BY

DR. E. S. PRIESTER.

Read 4th July, 1945.

THE SCIENTIFIC APPROACH TO NATIONAL HEALTH

BY

LT.-COL. H. GLUCKMAN,
Minister of Health.

Popular Evening Lecture, delivered 3rd July, 1945.

South African Journal of Science, *Vol. XLII, pp. 101-104*
June, 1946.

FIELD EVALUATION OF LANGEBAAN ROCK PHOSPHATE

BY

Dr. Thos. D. Hall, *Agricultural Adviser,*

AND

Dr. D. Meredith, *Senior Agronomist,*

TO

African Explosives and Chemical Industries, Ltd.

Read 2nd July, 1945.

Introduction.—The development of a South African Phosphate Rock Industry is a matter of great economic importance to the country. When a deposit of phosphate rock can be found and treated to make it suitable for use as a fertiliser, the resulting fertiliser must be tried out in the field before definite recommendations can be made concerning its use. This paper gives the results of a three year test with Langebaan Rock Phosphate prepared by the Mineral Research Laboratory of the University of the Witwatersrand.

Material.—The material was obtained from the Langebaan deposit in the Western Cape Province, near Malmesbury, and was supplied in two forms—calcined and uncalcined. The uncalcined material is described as follows, with respect to grading and chemical analysis.

Grading:	plus 200 mesh	...	2·4%
	plus 300 mesh	...	1·5%
	minus 300 mesh	...	96·1%
Chemical Analysis:	Total P_2O_5	...	15%
	Citric Soluble P_2O_5	...	15% (Robinson Test.)

The calcined material had the following chemical and physical composition:

Grading:	plus 200 mesh	...	2·6%
	plus 300 mesh	...	2·3%
	minus 300 mesh	...	95·1%
Chemical Analysis:	Total P_2O_5	...	15%
	Citric Soluble P_2O_5	...	14·5% (Robinson Test.)

With regard to the chemical composition, samples of these materials were analysed by the Division of Chemical Services, with the following results:—

Langebaan Rock—uncalcined:	Total P_2O_5	...	14·77%
	Citric Soluble P_2O_5	...	4·26%
Langebaan Rock—calcined:	Total P_2O_5	...	15·34%
	Citric Soluble P_2O_5	...	10·22%

Field Work.—The two types of phosphate were tested out in the field at Frankenwald, the Botanical Research Station of the University of the Witwatersrand, on a sandy soil which was under virgin veld until the winter prior to the commencement of the experiment.

The soil is deficient in phosphate, and has a pH ranging from 5·5 to 6·0.

One crop of maize was grown with an application of the phosphatic fertilisers and was followed by another crop of maize and one of soybeans, without further phosphatic applications. The treatments compared were 1,058lb. uncalcined, 1,058lb. calcined rock per morgen, 635lb. 19·1% superphosphate per morgen and a control treatment without fertiliser.

The total amounts of P_2O_5 applied per morgen at the commencement of the experiment, according to the Division of Chemical Services analysis were thus: uncalcined rock 156lb., calcined rock 162lb. and superphosphate 127lb.

Natal-8 row maize was grown in the first season, Potchefstroom Pearl in the second and a non-shattering variety of soybeans in the third season.

Three plots of each treatment were planted in randomised blocks and every effort was made to ensure perfect stands by planting three seeds of maize at each planting point and later thinning out to one plant. The soybeans were planted thickly and replanted where necessary and later thinned out to four inches between plants.

Results.—The average yields obtained over the three seasons are summarised in Table 1.

Table 1: Yields of maize and soybeans with Langebaan Rock Phosphate and Superphosphate:

Treatments.	Yields of grain in pounds per morgen.		
	1941-42 Maize.	1942-43 Maize.	1943-44 Soybeans.
No Fertiliser	1384	2226	1187
With 1058lb. uncalcined Langebaan rock per morgen	2389	4097	1860
With 1058lb. calcined Langebaan rock per morgen	2148	3504	1555
With 635lb. 19·1% Superphosphate per morgen	3529	4990	2042
Rainfall per season October to March	23·04in. November exceptionally dry.	25·06in. Well distributed rainfall.	30·30in. Excessive rain in February.

The results were subjected to statistical analysis, which showed that in the first two seasons, the differences between all fertiliser treatments and the no fertiliser treatment were highly significant. In the third year, the yields in the uncalcined Langebaan rock and the superphosphate treatments were significantly better than the yield in the control treatment, but the difference between the control and the calcined rock treatment was not significant.

In Table 2, the yields of grain for the three seasons are shown as yields per pound of total P_2O_5 applied. In working out these results it was assumed that 33·1-3% of the total phosphate applied became available in the first season, 20% in the succeeding season and 10% in the third season. The yields on the no fertiliser plots were subtracted in each case, the figures quoted being increases due to the fertiliser treatments.

Table 2: Increases in Grain Production due to Fertiliser Treatments:

Treatment.	Pounds grain per lb. of P_2O_5			
	1941-42	1942-43	1943-44	Average.
1058lb. uncalcined rock	19	60	42	40·3
1058lb. calcined rock	14	40	23	25·7
635lb. Superphosphate	51	110	65	75·3

Discussion.—The yields shown in Table 1 indicate clearly that the uncalcined rock has given consistently higher results than the calcined material, and furthermore, that the superphosphate is superior to the uncalcined rock. The higher yields in the second season are probably due to the favourable rainfall, both as regards amount and distribution, and also to the fact that the first season's crop was on virgin soil.

It is of interest to note that on this relatively poor Frankenwald soil yields of up to 11 bags grain per morgen without fertiliser are possible, if care is taken to ensure perfect stands and weeds are controlled.

The figures quoted in Table 2 show that the phosphate in the uncalcined rock gave better results than that of the calcined material up to the third season after the initial application. The phosphate in the superphosphate was similarly more available than that of the uncalcined rock, and the increase in production was maintained up to the third season.

Although calcining has been proved to be absolutely necessary to enable the raw rock to be ground, the calcined material does give such a high yield of grain per unit of P_2O_5 as the uncalcined. The experiment has shown that superphosphate gave the highest yield per unit of P_2O_5. Unfortunately the grade of Langebaan

rock so far produced in quantity has been too low in total phosphoric oxide for superphosphate manufacture, and much of it contains too much iron and alumina as well.

Summary.—An experiment to test the value of Langebaan rock phosphate in the field, as a fertiliser, is described. The calcined material was compared with the uncalcined, and a treatment with 19·1% superphosphate was included.

The fertilisers were applied to the first maize crop, and then a second maize crop and a soybean crop were grown without further applications in order to test the residual effects of the three types of phosphatic fertiliser.

All three phosphatic fertilisers gave significantly higher yields than the no fertiliser treatment for the first two years, and the uncalcined rock and superphosphate were also significantly better than the no fertiliser in the third year.

Calculation of the results in terms of increase in yields of grain above those produced by the no fertiliser treatment, showed that superphosphate gave the highest returns with an average of 75·3lb. grain per pound of P_2O_5. The uncalcined rock gave 40·3lb. and the calcined rock 25·7lb. grain per pound of P_2O_5.

SOUTH AFRICAN JOURNAL OF SCIENCE. *Vol. XLII, pp. 105-118, June. 1946.*

ROOT STUDIES IN HIGHVELD GRASSLAND COMMUNITIES

BY

J. A. COETZEE, M. I. PAGE

AND

DR. D. MEREDITH, *Senior Agronomist to the African Explosives and Chemical Industries, Limited.*

Read 2nd July, 1945.

Introduction.—While it is true that the importance of the roots of plants in providing the aerial portions with the water and nutrients required for normal growth is widely recognised, nevertheless, owing to the difficulty of studying the roots *in situ*, little research has been attempted on their distribution in the soil. Furthermore, the study of the rooting habits of grasses in communities has been given but little attention, although it is evident that the development and distribution of the rooting systems of the different species play an important role in their growth and in the relative distribution of the species within the community. The studies reported in this paper were undertaken in order to provide information on the development of root systems in some Highveld grassland communities.

Review of the Literature.—Weaver (1919), McDougall (1933) have shown the effect of environment on the roots of grasses and other plants, and Dittmar (1928) Russell (1927) and Klapp (1930) have all demonstrated the effect of grazing on root development. Stapledon and Milton (1930), Jones (1933), Graber (1929) and Graber and Ream (1931) have also described the effects of clipping, grazing and frequency of mowing on the development of grass roots. The effect of fertiliser treatments on root development has been investigated by Laird (1930), Harrison (1931) and Evans (1931). Pavlychenko (1937) and Weaver and Clements (1938) have indicated the important role competition plays in the development of root systems of plants.

Murray and Glover (1935), Scott and van Breda (1936, 1937 and 1938), and Rose-Innes (1939) all studied the distribution of South African native grasses and other plants in various areas. The effects of fertilising and clipping on South African High Veld grasses have been investigated by Weinmann (1943, 1944) who has shown that marked effects on weights and competition were obtained.

Technique.—All the work reported in this paper was carried out at Frankenwald, the Botanical Research Station of the University of the Witwatersrand, fourteen miles north of Johannesburg.

The method used for exposing the root systems in these investigations was based on that employed by Weaver (1919),

somewhat modified in accordance with the experience of Murray and Glover (1935). A trench a yard wide and about five feet deep was dug a few inches away from the plants or community of plants selected for study. Care was taken to cut the face of the trench next to the plants vertical. so as to facilitate excavation of the roots. The working face was then marked out in 6-inch squares by means of iron pegs and thin wire. Murray and Glover (1935) used string. but it was found that when sprayed continuously with water, the string sagged, making accurate charting difficult. The implements found to be most suitable for exposing roots were pieces of 8-gauge smooth wire sharpened to a point or flattened to give a chisel-like edge at the one end. Dissecting needles were tried but they broke in hard soils. From time to time the soil about the roots was loosened by means of a jet of water from a stirrup pump, operated by an attendant. Compressed air was not used in these investigations.

As the roots were exposed, they were charted to scale on paper, using a scale of 1 inch = 6 inches. Notes were taken as the work progressed on the types of roots, frequency of branching, root distribution in layers in a community and on the soil texture. Soil samples were taken from all pits at different levels for examination in the laboratory. Plates 1 and 2 illustrate the methods used in charting the root systems.

As each pit was dug a square yard of veld was marked out at one end, and the plant cover having been shaved off at the surface with a sharp spade, the soil was excavated in four inch layers to a depth of two feet. Each soil layer was placed in a clean bag. The soil samples thus obtained were dried in the bags or in clean feeding troughs and then sieved over a sieve with 20 meshes to the inch. All roots were then collected in clean paper bags and all insects in each layer were collected and placed in preservative.

The roots were subsequently dried on a grass drier, weighed and ground for analysis: The insect specimens were sent to Rhodes University College, Grahamstown, for identification.

Description of Rooting Habits in Communities.

(a) *Root Habits and Soil Types.*—The communities selected for these studies were widely spaced over the station and therefore physical analyses of the soils in the different areas were carried out for the purpose of determining the relationship, if any, between soil texture and root behaviour.

In general, Frankenwald soils are sandy loams usually intermixed with quartz pebbles and stones at a depth of 8 to 16 inches. Underlying this stony layer is a layer of decomposed old granite which merges into undecomposed impervious granite at a depth of two to three feet. Cleavage spaces in the rock are filled with soft grey soil. Two main soil types were encountered, a red and a yellow soil, varying more in colour than in any other characteristic.

Physical analyses of soil samples from the various sites gave the following range for the surface soil, to a depth of four inches.

	per cent.
1. Maximum water retaining capacity	42·8—46·9
2. Colloid content	11·1—22·5
3. Clay content	9·2—18·0
4. Loss on ignition	2·6— 3·7
5. pH (Beckman pH meter)	4·1— 5·7

It was found that the values for the above determinations tended to increase with increase in depth, while the soil reaction became less acid.

(b) *Priseral Communities.*—The *prisere* embraces the successional stages in undisturbed natural sequence, and includes the early grass stage, the later grass stage, the final grass stage and the climax mixed scrub. In these investigations, communities of the final grass stage with relicts of the early and later grass stages were studied. In addition, certain communities were investigated in pastures which had been planted from eight to ten years previously. Certain areas of the final grass stage of the *prisere* had been disturbed by fertilising and grazing treatments over a period of ten years, with the result that some members of the early and later grass stages of secondary succession have made an appearance, although all the priseral species are still present. The root production and development of certain species in these camps, which had been mown and not grazed for two seasons, were compared with those of the same species in the undisturbed final grass stage of the *prisere*. The final grass stage at Frankenwald consists of a mixture of fairly tall grasses such as *Trachypogon plumosus*, *Tristachya hispida*, *Brachiaria serrata*, *Heteropogon contortus*, and *Elyonurus argenteus*, along with a prostrate species *Digitaria tricholaenoides* and several non-grass species. The rooting habits of some of the typical members of this community and of some of the minor species are described in this paper.

1. *Trachypogon plumosus.*—Yellow and fleshy in texture, the roots having an average diameter of 1·75 mm. No superficial horizontal roots were found in the shallow soil, but most of the roots penetrated the soil obliquely for a distance of about 9 inches before turning downwards. Although there were no superficial laterals, the majority of roots in both the red and yellow soil types restricted their activities to the 1½ ft. level. A large number of roots, however, terminated at a depth of 2½ to 3 feet. The roots are fairly well branched, with the secondary roots short, thick and yellow at their extremities. A count of the roots showed there were on an average 8 secondary roots per five inches of main root in the top 8 inches of soil, and 22 per 5 inches in the layer extending from 8 to 18 inches. Tertiary roots were found up to 10 inches in length and were well branched. The average number of roots for a plant with a basal circumference of 8 inches was found to be 278. Fairly large

numbers of root tips are produced by the rooting system, but root hairs are not produced in great abundance. The species does not appear to absorb moisture from the surface layer of soil on account of the sparse branching in the top 8 inches of soil.

2. *Tristachya hispida.*—The whole root system is dark brown, coarse and easily broken. The average diameter of the main roots was between 1·75 and 2 mm. In both the soil types encountered the root system was shallow, the maximum depth being 1½ ft., although most of the roots terminated at a depth of 1 foot.

There were no horizontally terminating main roots. On the whole the root system was fairly well branched to the third order. At a depth of about 6 inches, the main roots produced long and vertically penetrating secondary roots, of which there were up to 22 per 5 inches of main root. The average number of roots produced by a plant with a basal circumference of 8 inches was 287. *Tristachya hispida* is a shallow rooted grass but is not equipped with superficial or extremely shallow horizontal roots. As in *Brachiaria serrata*, the mucilaginous sheath with some embedded soil particles found on the roots probably serves as a protection against loss of water from the root.

3. *Elyonurus argenteus.*—The roots are cream, tending to become brown later, fleshy, flexible and about 1·4 mm. in diameter. Few branches seem to be given off, and there are about 12 secondary roots per five inches of main root. No horizontally terminating roots were found in the surface layers of the soil and most roots terminated at a depth of 1½ to 2 feet. The average number of roots produced by a plant eight inches in circumference was 488. *Elyonurus* is shallow rooted and the absorption surface of the root system is not great because of the poor branching habit and the absence of root hairs along the length of the roots. It produces more roots, however, than any other member of this community.

4. *Heteropogon contortus.*—In the first few inches the roots are yellow, particularly the tips of the secondary branches. At the lower levels, however, the roots become cream in colour. In the upper levels the roots are soft and fleshy, but are drier and coarser in the deeper levels. The average diameter was 1·2 mm. Many roots terminate close to the surface of the soil, being but ⅛ of an inch below the surface and extending for from 3 to 9 inches. The maximum depth of penetration was about 2½ ft. The root system of this species is well branched, particularly in the surface soil, and branches up to the fifth order were found. This species is shallow rooted and the region of maximum absorption seems to be close to the surface of the soil, although absorption seems to occur down to a depth of 2½ ft. On account of the numerous branches and presence of root hairs along the length of the roots, the absorptive capacity seems to be of a high order.

5. *Brachiaria serrata*.—The roots are creamy-white in colour and soft and fleshy in texture. Near the surface the diameter was about 3 mm. but deeper in the soil this decreased to about 1·5 mm. The roots do not branch freely but are covered with long root hairs visible to the naked eye. All roots penetrated downwards to a depth of 2½ feet. A thick layer of mucilage occurs on the outside of the root, in which the soil particles are embedded. Soil particles are also held by the root hairs, forming a soil sheath, although in the deeper levels no adhering soil particles are present and the roots are white. This species may be considered deep rooted and not dependent on the surface soil for its moisture supply. It is able, however, to absorb moisture along the whole length of the roots by means of the numerous long root hairs. On account of its poor branching habit, the root system does not produce large numbers of root tips.

6. *Digitaria tricholaenoides*.—Short stolons occur, sometimes in a tuft of another species, from which four or five orange-yellow roots arise. The roots are wiry in texture and not easily broken. They are almost as thin as cotton threads and both the secondary and tertiary roots are extremely fine. The secondary roots sometimes attain a length of 4 to 6 inches where the soil is soft. No superficial laterals were found, although the roots were a little more finely branched in the surface soil. A count showed that in the top 8 inches of soil there were 83 secondary roots per 5 inches of main root and 60 per 5 inches in the 2 to 3 foot layer of soil. The maximum depth observed was 3 feet. *Digitaria tricholaenoides* is thus a species with a moderately deep root system. The roots are able to absorb moisture along their whole length, because of the well branched system. Figure 1 shows a typical bisect of the final grass stage.

(c) *Species of minor importance*.

1. *Alloteropsis semialata*.—The root system was only studied in a camp which had been fertilised. The roots are hard and yellow, having almost a woody texture. The maximum depth reached was 3 feet. The branching was not extensive, the few secondary and tertiary branches being similar in appearance to those of *Digitaria tricholaenoides*.

2. *Setaria flabellata*.—The root system is cream in colour, with the roots about 1 mm. in diameter in the upper soil layers and tapering as the roots penetrate the soil. No roots were found terminating in the surface soil and most of them penetrated to a depth between 3 and 5½ feet. The whole root system is well branched to the fifth order. There were from 10 to 13 secondary roots per 5 inches of main root and from 30 to 35 tertiary per inch of secondary root. Numerous stolons, about 4 mm. in diameter are produced. The stolons are well protected by a ribbed, straw-coloured sheath, and have only one bud in a terminal position. The stolons penetrate the soil obliquely for 3

to 4 inches, then curve upwards. The stolons do not produce roots usually until the bud is above ground.

3. *Monocymbium ceresiiforme.*—The roots are creamy-yellow in colour and about 1 mm. in diameter. The root system is not well branched though the branches given off are fairly long and fine. The absorptive surface is not great because comparatively few and short secondary roots are given off, and no root hairs are found on the older main roots.

Fig. 1 and *Plate 1* show a typical bisect of the main grass species (a), (b) and (c).

(d) *Root Systems of Grasses in the Subsere.*

The *subsere* is the progressive development from one stage to another on soils which have been disturbed by ploughing or grazing or even by frequent burning. This development is commonly known as *secondary* succession. As in the study of the grasses in the *prisere*, the grasses in the *subsere* were investigated in several sites.

(1) *Grasses of the early grass stage.*

1. *Cynodon Dactylon.*—Plants were connected by an extensive system of rhizomes existing at depths of from 2 to 6 inches. The diameter of the rhizomes was 2 to 3 mm. These rhizomes ran in all directions, branching freely, and at irregular intervals gave rise to stems. From the nodes of these tough rhizomes, which were from 12 to 36 mm. apart, whorls of roots arose, consisting of from 2 to 5 roots (usually two or three). The roots varied greatly in length and diameter. The short ones were only from 6 to 12 inches long and from 0·5 to 1mm. in diameter. The longer roots were thicker, about 2 mm. in diameter and penetrated the soil vertically downwards to a depth of 5 feet. Throughout their course, these roots were well supplied with both short and long branches. The short branches varied in length from 0·5 to 7 inches while the longer ones were about two feet in length. These branches penetrated the soil in all directions and were covered with fine rootlets. The root system forms an efficient absorbing system.

2. *Aristida congesta.*—The abundant roots varied from 1 to less than ·5 mm. in diameter. The maximum depth varied from 18 to 24 inches but the majority of the roots was confined to the upper 12 inches of soil, in which layer a dense network of roots was found. The roots branched profusely to the second and third order, were yellowish white in colour, and extremely well branched at the ends.

3. *Eragrostis chalcantha.*—This species showed a dense network of creamy-white roots, which spread laterally from 3 to 5 inches and occupied the soil thoroughly, from the surface to a depth of about 6 inches, below which depth relatively few roots extended. The roots were slender from ·3 to ·5 mm. in diameter and profusely branched with fine laterals usually less than an

inch in length. The branching continued to the tips of the roots, where the laterals were usually longer and more numerous.

4. *Eragrostis nebulosa*.—The abundant roots of this species thoroughly occupied the surface soil. The long roots penetrated to a maximum depth of 3 feet, but the average depth was about 32 inches, with most of the shorter roots in the top 18 inches of soil. All the roots were profusely branched with threadlike laterals ·1 to ·2 mm. in diameter, from 1 to 6 inches in length, and covered with rootlets. The roots are white, from 1 to 2 mm. in diameter and are covered with a thick sheath of sand particles, which are difficult to remove.

(2) *The later grass stage.*

1. *Hyparrhenia hirta*.—This species had a well developed root system which was the longest of any species examined. Several roots reached depths of over 5 feet. The roots spread laterally from the base of the plant in a horizontal or oblique direction for 3 to 18 inches before they turn abruptly downwards and penetrate the soil with a tortuous course, practically vertically, to an average depth of 45 inches. Most of the roots, however, were confined to the first 3 feet of soil. All roots were well branched, with laterals from a few millimetres to 24 inches in length and ·1 to ·5 mm. in diameter. These abundant threadlike laterals branched profusely to the second and third order, so that the soil to a depth of 45 inches was filled with a mass of roots. In this species the roots are creamy white, 1·5 to 2 mm. in diameter, and thickened and extremely well-branched at the ends.

(e) *Communities subjected to Grazing, Fertilising and Mowing Treatments.*

(1) *Members of the Priseral Community*.—As will be noted in a later section on the quantitative distribution of roots in the soil, the effects of grazing, fertilising and mowing treatments on members of the priseral community are not marked and the most that can be said is that perhaps the treatments have reduced root penetration to some extent. There is some evidence that *Trachypogon plumosus*, for instance, behaves as a shallow rooted species in fertilised camps and as a deep rooted species in unfertilised areas, but more work will have to be done before definite statements could be made.

(2) *Planted Grasses.*

Paspalum dilatatum.—The coarse fibrous roots of this species, varying from 1 to 2 mm. in diameter, penetrated the soil to an average depth of 24 inches, though the greatest root depth examined was 42 inches. The roots branched profusely up to the tips, and the laterals were from 1 to 9 inches long and ·5 to 1 mm. in diameter. These laterals also branched freely so that the soil to a depth of 18 inches was thoroughly occupied by the roots. The colour of the roots was cinnamon brown and the tips were thick and fleshy.

Digitaria Pentzii.—This is a stoloniferous grass and from the nodes of the stolons, which were 5 to 10 millimetres apart, whorls of roots arose, consisting usually of two or three roots, though occasionally five were present. The roots varied from ·5 to 1 mm. in diameter, were brown with thick ends and reached a depth of 4 feet, although most of them were confined to the upper 2 feet of soil. Branching was profuse right up to the tips with much divided laterals from 1 to 4 inches long and ·1 to ·2 mm. in diameter.

The roots were covered with a fine network of rootlets from 1 to 5 mm. in length. Long, well-branched horizontal roots were found at depths of 1 to 4 inches and were traced for distances of over 2 feet. The laterals from these frequently ascended vertically and ended in well branched termini only 1 to 2 mm. below the surface of the soil.

Fig. 2 shows a typical bisect of the species in class (e).

(f) *Quantitative Distribution of Roots.*

The percentage distribution of roots in four-inch layers down to a depth of 24 inches in certain camps is shown in table 1.

TABLE I—Percentage Distribution of Roots in the Soil.

Site and Treatment.	Percentage Distribution of Roots by Weight. in. 0-4	in. 4-8	in. 8-12	in. 12-16	in. 16-20	in. 20-24	Total % in top 8in.
Camp A 11: Complete protection -	67·1	18·2	9·2	2·0	2·2	1·3	85·3
Camp A 6: No fertiliser -	68·3	14·5	7·4	4·5	3·3	2·0	82·8
Camp A1: P* - -	66·3	13·9	7·3	4·7	4·0	3·8	80·2
Camp A2: NP - -	52·1	28·1	9·3	5·2	3·0	2·3	80·2
Camp A 3: NPK - -	57·6	15·7	10·5	7·3	4·9	4·0	73·3
Camp A 5: N_3PK - -	55·5	15·9	8·8	8·8	5·6	5 4	71·4
Camp F 5: No fertiliser -	46·2	15·4	11·9	10·9	8·4	6·9	61·6
Camp F 5: NPK* - -	36·1	16·4	13·0	12·7	12·3	9·3	52·5
Camp F 3: N_3PK* - -	59·4	15·7	10·3	7·3	5·1	2·1	75·1

It should be noted that with the exception of Camp F5, NPK, no fertilisers had been applied for two seasons. P represented 400 lb. rock and superphosphate mixture per morgen per annum, N 200 lb. and N_3 600 lb. sulphate of ammonia, per morgen per annum and K 80 lb. potassium chloride per morgen per annum.

* The yields in the three cases Camp A1, P, Camp F5, NPK and Camp F3, N_3PK, are given as air-dry roots and have not been corrected for adhering sand.

(g) *Distribution of Insects and Earthworms in Soil Layers in Certain Camps.*

The data with regard to the distribution of earthworms and insects per square yard to a depth of 24 inches showed that the number of earthworms varied from 0 to 8 and insects from 2 to 64. The insects included mainly members of the families Scarabeidae and Elateridae and millipedes.

Discussion and Conclusions.

It is clear from the foregoing description of roots and their distribution in the soil that no clear line of demarcation exists between the species within the community, the distribution of their roots being apparently affected as much by soil type and texture, drainage and, possibly also fertility, as by specific differences. There can be no doubt, furthermore, that in grassland communities which are grazed, the intensity of defoliation has a marked effect on the root development of the grass species. The studies of the same species in different sites reveal differences in depth of penetration, which seem to be due to soil or treatment differences.

These studies show that the grass cover depends on a remarkable network of roots, which penetrates the soil in all directions. Many roots go down deeply, but the bulk of the root mass is found in the upper layers. There is some evidence that species differ with respect to the soil layers in which most of their roots are found.

Our data show that while there is a certain amount of variation in the amounts of roots produced, it is evident that the upper 8-inch layer of soil contains three quarters of the root mass. The results indicate further that fertiliser treatments have reduced the weight of roots, the phosphate treatment apparently having a more marked effect than the other treatments. They also give some indication that the heavy nitrogen treatment (N_3PK) has encouraged deep rooting and has thus reduced the proportion of roots in the top 8 inches.

It is of interest that the dry weights of roots of grassland to a depth of 24 inches vary from 2 to 3·8 tons per morgen, and that of this large amount more than half is usually to be found in the top 4 inches.

It is also noteworthy that the Frankenwald soil, down to a depth of 24 inches, under veld or planted pastures, has a small worm and insect population. From our data it may be concluded that fertiliser treatments have had no harmful effects on insect and worm populations.

It may be concluded from these studies that the root systems in grassland communities are penetrating and widespread and fill up the soil mass with an efficient network of absorbing rootlets.

In conclusion, it must be emphasised that, owing to the nature of these investigations, adequate replication was not

possible, and hence there is a real danger that the sites selected may not have been truly representative of the communities. The data presented in this paper must, therefore, be accepted with reserve, until further work along these lines can be undertaken.

SUMMARY.

Numerous bisect pits were excavated in grassland communities on the Frankenwald Botanical Research Station. Most of the bisects were excavated down to a depth of 5 feet, and the root systems were carefully charted.

Descriptions are given of the rooting systems of most of the important grass species of the various stages of succession occurring in Frankenwald veld.

In some instances, square yards of veld were excavated to a depth of 24 inches in 6 four-inch layers and the roots were sieved out of the various layers, dried and weighed.

Root weights showed that with two exceptions, more than 70% of the roots of veld occur in the top 8 inches of soil and more than 50% in the top 4 inches. Insects and earthworms were collected at the same time as the roots were sieved from the square yard samples.

BIBLIOGRAPHY.

DITTMAR, H. J.: "A quantitative study of the subterranean members of 3 field grasses." *Amer. Jour. Bot.*, **25**: pp. 654-657 (1938).

EVANS, T. W.: "The root development of New Zealand, Browntop, Chewing's Fescue and Fine-leaved Sheep's Fescue under putting green conditions." *Jour. Bd. Greenkpg.* Res. **2**: pp. 119-184 (1931).

GRABER, L. F.: "Penalties of low food reserves in pasture grasses." *Jour. Am. Soc. Agron.* **21**: p. 29 (1929).

GRABER, L. F. and REAM, H. W.: "Growth of Bluegrass with various defoliations and abundant nitrogen supply." *Jour. Am. Soc. Agron.* **23**: p. 938 (1931).

HARRISON, C. M.: "Effect of cutting and fertiliser applications on grass development." *Plant Phys.* **6**: pp. 669-685 (1931).

JONES, M. G.: "Grassland management and its influence upon the sward (Part I): Factors influencing the growth of pasture plants." *Emp. Jour. Exp. Agric.* **1**: pp. 43-57 (1933).

KLAPP, E.: "Uber die wurzel verbreitung der grasnarbe bei verschiedener nutzungsweise und pflanzen gesellschaft." *Pflanzenbau* **19**: pp. 221-236 (1943).

LAIRD, A. S.: "A study of the root systems of some important sod-forming grasses." Univ. of Florida, *Agric. Exprmt. Sta. Bul.* **211** (1930).

McDOUGALL, W. B.: "Plant Ecology." Lee and Febiger (1941).

MURRAY, S. M. and GLOVER, P. E.: "A preliminary study of the root development of certain South African Highveld grasses." *So. Af. Jour. Bot.* **2**: (1935).

PAVLYCHENKO, T. K.: "Quantitative study of the entire root systems of weeds and crop plants under field conditions." *Ecol.* **13**: (1937).

ROSE-INNES, R.: "Some observations of the nature and causes of secondary succession on certain areas of Frankenwald and in the Highveld." *M. Sc. Thesis*, University of the Witwatersrand (1939)

RUSSELL, E. J.: "Soil Conditions and Plant Growth." Longmans, Green & Co., London (1927).

SCOTT, J. D. and VAN BREDA, N. G.: "Preliminary studies on the root systems of the Rhenosterbos *Elytropappus rhinocerotis* on the Worcester Veld Reserve." *This Journal*. **33**: pp. 560-569 (1936).

SCOTT, J. D. and VAN BREDA, N. G.: "Preliminary studies on the root system of *Galenia africana* on the Worcester Veld Reserve." *This Journal*. **34**: pp. 268-274 (1937).

SCOTT, J. D. and VAN BREDA, N. G.: "Preliminary studies on the root systems of *Pentzia incana-forma* on the Worcester Veld Reserve." *This Journal*. **35**: pp. 280-284 (1938).

STAPLEDON, R. G. and MILTON, W. E. J.: "The effect of different cutting and manurial treatments on the tiller and root development of Cocksfoot." *Welsh Jour. Agr.* **6**: pp. 166-174 (1930).

WEAVER, J. E. and CLEMENTS, F. E.: "Plant Ecology." McGraw-Hill Pub. Co. (1929).

WEAVER, J. E.: "Ecological relations of roots." *Carnegie Inst. Wash. Pub.* **286** (1919).

WEINMANN, H.: "Yields and chemical composition of pasture herbage as influenced by fertilising and frequent clipping." *This Journal*. **40**: pp. 127-134 (1943).

WEINMANN, H.: "Root reserves of South African Highveld grasses in relation to fertilising and frequency of clipping." *Jour. So. Af. Bot.* **10**: pp. 37-53 (1944).

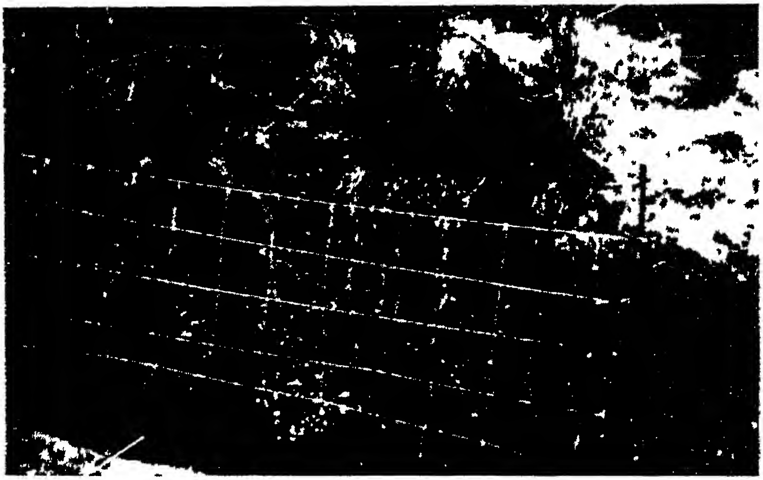


Plate 1

Plate 2

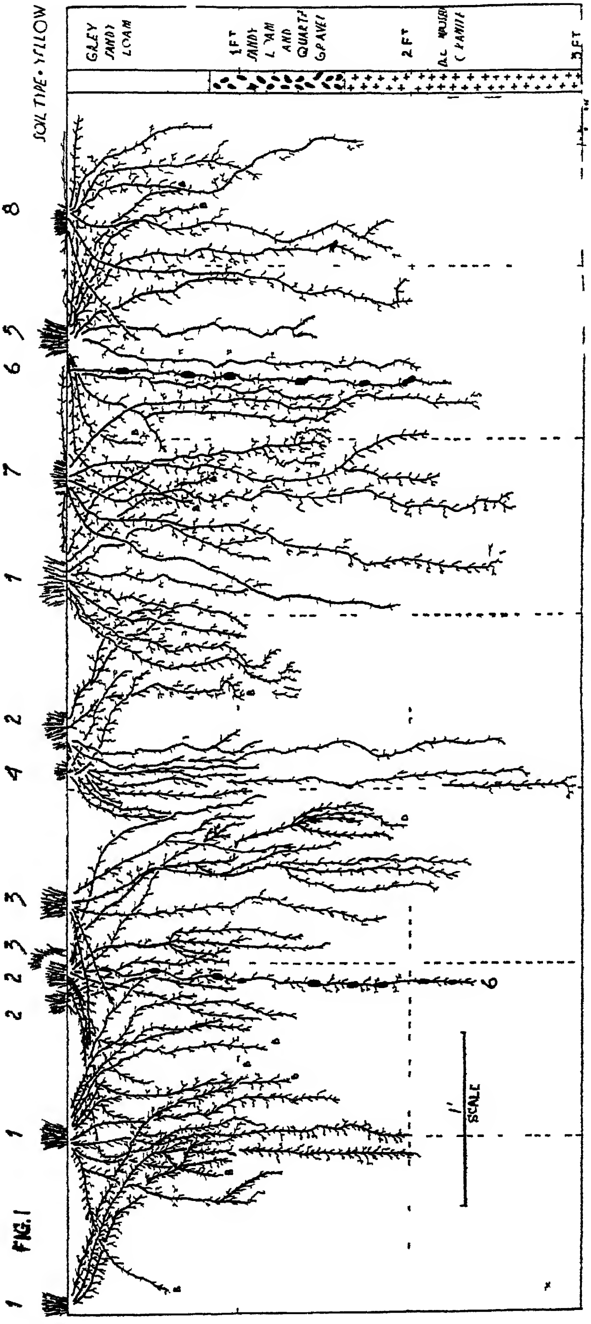


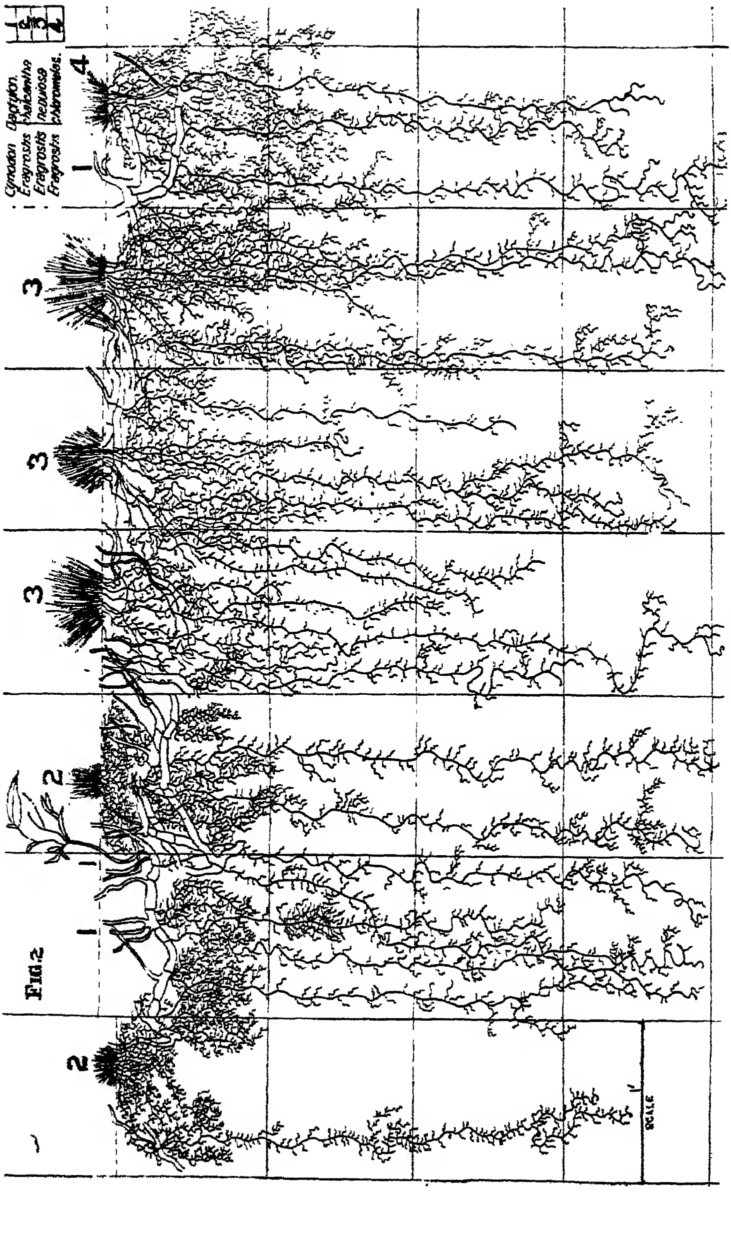
FIG. 1

ROOT BISECT CHART

Final grass stage of the priserie protected veld

1 *Tristachya Hispida* 5 *Elyonurus Argenteus*
2 *Trachypogon Plumosus* 6 *Oldenlandia Amatymbica*
3 *Eragrostis Sp* 7 *Heteropogon Contortus*
4 *Digitaria Tricholaenoides* 8 *Monocymbium Ceresiiforme*

B Broken D Decayed



Bisect showing the Root Distribution of certain grasses of the Earlier Grass Stage of Lower Secondary Succession.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XLII, pp. 119-121, June, 1946.*

THE ASSIMILATES OF WILTING AND FROSTED LUCERNE

BY

DR. M. HENRICI,

Senior Professional Officer, Veld Reserve, Fauresmith. Division of Botany and Plant Pathology.

Read July 2nd, 1945.

It has been shown that during wilting, the daily change of the assimilates in lucerne is greatly disturbed. Not only is the time of the maxima of starch values altered, but also the proportion of the different assimilates. This result was obtained from samples collected every few hours during a period of 30 hours. It was thought advisable to follow up the effect of wilting during a long period of a few weeks. With a limited staff it was not feasable to collect samples every few hours over a long period, as the analyses could not be completed in a reasonable time. Thus, between 12 a.m. and 2 p.m. was chosen for sampling, as it was thought this time would show up the effect of wilting clearly enough and would at the same time be convenient to complete the sampling in day-time, as well as the determinations of fresh matter.

The methods used for sampling and analyses were the same as previously outlined (Henrici 1944). A thermohygrograph was put into the lucerne lands, 5 feet above the soil so as to have a constant record of moisture and temperature.

As is well known wilting is not a regular process and a plant wilted one day may recover on the following day if the moisture content of the air increases or the temperature decreases. As the fresh matter was determined daily, any improved condition of the plant was reflected in an increased water content.

Up to now three progressive wilting experiments have been made. One from the end of September 1944 to the 16th October (Provence lucerne), one in October 1944 (Hunters River lucerne), and one during February 1945 (Provence lucerne). The lucerne was sampled without being watered; the water content of the fresh matter dropped by 28 percent to 30 percent between the initial and end stage. At the beginning drooping occurred with the loss of only 2 percent water. The ratio of leaves to stems in both October experiments was 1:1 and decreased to 1:0.92.

The results in general show a low starch content. To begin with, it was higher in leaves than in stems, but under 2 percent.

Later the stems more often contained more starch than the leaves, but all values dropped to a very low level, under 0.5 percent at times. Although there were fluctuations, the tendency of starch to decrease is clearly seen until the very last few days before death, then suddenly an increase occurred, to over 2.5 percent for leaves and 1.5-2 percent for stems. Then death occurred.

At the first wilting (for about three days), the total sugar content was over 3 percent in leaves and stems after which it dropped.

TABLE I—Changes of Sugars in Progressive Wilting.

Value in Percentage of Dry Matter.

	Stem.	Leaves.
Average of Total Sugar:		
1 Third Day	3·4	3·05
4 Ninth Day	2·6	1·7
10 Nineteenth Day	2·6	1·8
Average of Reducing Sugars:		
1 Third Day	1·5	2·54
4 Ninth Day	1·57	1·41
10 Nineteenth Day	0·66	0·52
Average of Sucrose:		
1 Third Day	1·9	0·54
4 Ninth Day	1·01	0·63
10 Nineteenth Day	1·80	1·18

The changes of the sugar content are given in the attached table. It is noteworthy that the average total sugar content between the 4th and 19th day scarcely changed for leaves and stems, but whilst the reducing sugars continually decreased, the sucrose content increased in the last period of the experiment.

TABLE II—Changes in Starch and all Assimilates during Progressive Wilting. Value in Percentage of Dry Matter.

	Stem.	Leaves.
Starch:		
1 Third Day	1·08	1·52
4 Ninth Day	1·33	0·60
10 Nineteenth Day	1·31	1·61
Total Assimilates:		
1 Third Day	4·48	4·57
4 Ninth Day	3·93	2·30
10 Nineteenth Day	3·91	3·41

As a result of progressive wilting there is first a decided decrease in assimilates, especially noticeable in the decreased starch content. Further as in the wilting experiments of short duration photo-synthesis is largely restricted to the stems, yet in the second period of wilting the stems are also damaged, although much less than the leaves. The assimilation of the

latter is about 50 percent of normal, whilst that of the stems decreases by about 12 percent.

The higher starch and sucrose values for the third period of wilting are unexplained.

Experiments done with cut lucerne, which was allowed to wilt in the sun, and dry in 24 hours also showed increased activity just before death.

If reducing sugars are responsible for bloating of animals, then presumably the dangerous period of wilted lucerne is restricted to the first period. Their values in the later periods of wilting neither in stems nor in leaves exceed percentages experienced in well watered lucerne.

Frosted Lucerne.

In frosted lucerne the variations in total sugar content are large, particularly for the stem; there being less at night than in the day. The frosted leaves contain anything from 2.5-5 percent; while the stems contain up to 9.5 percent. Large amounts of starch were found in the leaves in addition to the sugars, especially in late winter. During the day the sugar and starch in leaves reaches 12 percent and decreases to 7 percent at night, which are higher values than found in summer optimum conditions.

So far no satisfactory explanation has been found for this phenomenon. But as already shown in the experiments on progressive wilting, there is a sudden increase in starch content prior to the death of the plant. Thus the high starch and sugar content after frost may be the result of a spasmodic reaction before death.

The important economic fact remains that frosted lucerne by its large sugar content may readily cause bloating in animals.

Experiments are being continued including the analysis of rootstocks and roots.

LITERATURE.

Henrici, M.: "The Effect of Wilting on the Direct Assimilates of Lucerne and Other Fodder Plants." *This Journal*, 41, 204-212 (1945).

South African Journal of Science, *Vol. XLII, pp. 122-130, June, 1946.*

CHEMOTHERAPY IN THE PROPAGATION OF SUGARCANE

BY

Dr. A. McMartin,

Experiment Station of the South African Sugar Association.

Read 2nd July, 1945.

Sugarcane is propagated vegetatively by means of stem cuttings laid horizontally in furrows.

Each cutting consists of three, four, or more nodes, at each of which is a single bud, a few rows of root primordia and an intercalary meristem (the growth ring). No regenerative changes are therefore required to initiate root and bud development.

Anatomically it may be regarded as a cylinder of hard sclerenchymatous tissue enclosing that of relatively soft texture, divided into sections by transverse plates of hard tissue at the nodes. The growth ring has a reduced amount of hard tissue, and as the cut is usually made through an internode, the ends are of soft tissue.

No traumatic response occurs after cutting, so that the cut end does not become healed with wound tissue.

Development from the Cutting.

Growth of the roots and buds on the sett is followed by development of roots at the base of the young shoot.

This primary shoot, by branching, eventually gives rise to the new plant, each branch of which, or tiller, has its own root system and becomes independent of the cutting.

Marked polarity is shown by the sugarcane cutting, the distal end functioning as a shoot pole and the proximal region as a root pole. Moreover, an inhibitory effect is exercised by the first developing, distal, shoots on those in a proximal position to them, a condition which is very pronounced under conditions for slow growth. A whole sugarcane stem when planted may give rise to only a few shoots at the distal end, whereas the same stem cut, gives rise to shoots from each portion.

Relation Between Primary Shoots, Tillers and Yield.

Statistical analysis of data collected from periodic population counts of field experiments has shown that a high negative correlation exists between the time of primary shoot production and the number of young tillers formed, i.e., the fewer the days for primary shoot emergence, the greater the number of secondary shoots from each primary. Thus vigorous growth of each bud leads to rapid tillering.

The population of stalks at harvest time, consisting of primary shoots and tillers, depends not only on the percentage of buds grown, but on the rate at which they have emerged. It has been found in experimental plots in the field that increased and quicker emergence produced a population which maintained its superiority till harvest over a population in which the percentage of buds grown was the same, but the rate at which they emerged was slower. High yields are thus correlated with a high emergence rate (unpublished data, McMartin).

Development of the Crop Under Field Conditions.

The number of buds which grow, and the time taken to do so, varies enormously under plantation conditions, but a large number of figures obtained, shows the average number of buds emerging in Natal to be only 26 per cent. of those planted, with a maximum of about 70 per cent. or more under favourable conditions. The time of emergence may vary from ten days to several weeks, and cases have been cited by planters, of some planted fields remaining dormant for three months before emergence began.

Failure of the cuttings to grow entails considerable economic loss—that of cane planted, of labour in replanting, and loss in final crop.

The establishment of a field of sugarcane is generally recognised as the most costly item in the rearing of the crop.

Causes of Failure.

In any one cutting failure of buds to develop may be due to polar inhibition, a condition which is exaggerated by the environmental conditions. Those favouring rapid development encourage a uniform emergence, but where conditions are not so favourable the first bud to develop may suppress the remaining ones to the extent of their losing vitality. A not uncommon condition is that in which each cutting produces only one shoot, emerging from one of the distal buds. This inhibition caused by the first developing shoot may render the other buds more susceptible to the activities of micro-organisms, or make them dry out, a condition also common in buds at the ends of the cuttings.

In addition to the failure of individual buds, the entire cutting may fail. When this occurs on any scale, serious loss is encountered.

Investigation into the cause of excessive failure of buds soon pointed to the trouble being pathological in nature.

Accordingly, the study and isolation in culture of fungi found associated with decaying or dead cuttings, and the inoculation of these cultures into healthy cuttings, has been undertaken.

Pathology of Decayed Cuttings.

The commonly occurring fungi on diseased cuttings are species of *Penicillium and Aspergillus*, *Fusarium moniliforme* Sheld. and *F. moniliforme* Sheld *var. subglutinans* Wr., *Colletotrichum*

falcatum Went., *Thielaviopsis paradoxa* (de Seyn) v. Hohn *Melanconium sacchari*, Mass., *Diplodia sp.*, and *Himantia stellifera*, Johnstone; in addition bacteria and various species of wild yeasts are often concerned. The latter groups have not yet been studied in detail. (These fungi have been recorded by McMartin (1937 and 1938).)

Thielaviopsis paradoxa constitutes the greatest single cause of mortality. It is a soil saprophyte, and in addition is epiphytic upon the stems of the growing crop, where it appears to do no harm. On the cuttings, however, it gains entrance through the cut end, and causes disintegration of the interior of the sett. A mass of black spores is produced down the centre, and at the same time, due to the formation of various esters, an odour of a distinctly ripe pineapple is given off—hence the name pineapple disease of cuttings.

An example of the heavy loss which can be caused by pineapple disease was provided by a field planted on one sugar estate in March, 1944. To ensure good germination at this time of the year four lines of cane were planted in each furrow: emergence was so bad however, that the whole field had to be ploughed out and replanted; in some areas the writer measured thirty yards between the emergent shoots. The black spore masses of *Thielaviopsis paradoxa* were conspicuous inside every examined cutting.

Cases of heavy financial loss have been reported frequently from various areas of the sugarcane belt, and in each case investigated the cause could be attributed to this specific disease.

Experiments in the Control of Diseases of Cuttings.

In 1936 small scale experiments were commenced in an attempt to reduce the loss among planted cuttings by the application to the soil of chemicals which had been found to have some therapeutic value in other spheres of agriculture or horticulture.

As primarily conceived, the objective attempted was to surround the cutting with a layer of temporarily and partially sterilised soil with the hope that the activities of the microorganisms would be inhibited sufficiently long to allow the cutting to become established.

This was tried in two different ways; firstly by applying to the soil itself a disinfectant, e.g., formalin, cresylic acid or Chestnut compound; secondly, by applying to the cutting a coating of one of the organo-mercurial seed disinfectants, Ceresan and Agrosan. The latter was performed by rocking the cuttings in large containers containing some of the disinfectant dust.

Cheshunt compound and cresylic acid had no effect on the percentage emergence of the buds, but the latter reduced the period of emergence, thus increasing the rate of emergence and increasing the tillering, producing a small increase in yield. Formalin increased both the percentage emergence and the rate of

emergence, thus leading to a higher yield at two years old than did cresylic acid. Spectacular results, however, were produced by the organo-mercurial treatments.

Ceresan treatment almost doubled the percentage of buds which emerged, reduced the emergence period, increased the rate of emergence between two and three times, and gave a yield which was 71 per cent. greater in tonnage than the untreated cane. Agrosan treatment increased the emergence percentage slightly more than Ceresan, but increased the period of emergence, thus exercising a depressing effect on the rate of emergence when compared with Ceresan; the final yield from this treatment, which although 50 per cent greater than that from the untreated cutting, was therefore less than that from Ceresan treatment.

The crop in this experiment went through its early development during a December drought in a sandy soil, and it immediately became apparent that a valuable means of increasing crop yields was available by the method of disinfecting the cuttings prior to planting. Several planters made trial plantings with very good results, but were forced to abandon the method on any large scale because of the expensive labour cost of treating the cuttings.

The effect of Ceresan applied to the soil in the furrow was next studied, compared with its application on the cutting. The first experiment was flooded, but data were obtained which indicated that under these conditions this material was slightly toxic when in close contact with the cane sett; applied to the soil a slight improvement was obtained, which however was not statistically significant.

A second experiment was planted, in an attempt again to use organo-mercurial compounds in the soil. Here Agrosan and Ceresan were applied either to the cutting, or to the soil; in addition each was used in conjunction with a mineral fertilizer mixture specially suitable for sugarcane, at the rate of 800lbs. per acre. These were compared with untreated cane. When cut two years later, the yield figures showed that the increase due to the fertilizer alone was 3 per cent. (which was not statistically significant); due to Ceresan on the cutting without fertilizer the increase was 24 per cent., but with fertilizer it was 31 per cent. The increase due to Agrosan on the cutting was 18 per cent., but with fertilizer it was 43 per cent. Ceresan and Agrosan in the soil, either alone or mixed with fertilizer, however, had no appreciable effect. This experiment was conducted on a good soil, and had ample rainfall during the germinating period; the untreated plots had no blanks to fill in, so that the above increases were not due to gaps in these plots, and must be attributed to a denser population and greater vigour. It was apparent, however, that the materials under normal conditions required to be applied to the cutting.

The effect of soil moisture on the response to these disinfectants has been made the subject of several pot experiments in the glasshouse These showed that different brands did not

behave in a similar manner, e.g., Agrosan exhibited a depressing effect on the rate of emergence under conditions of low soil moisture, an effect which disappeared as the soil moisture was increased, until with excess moisture conditions a marked benefit was obtained. Ceresan on the other hand, produced a marked response under dry conditions, but in wet soil exerted a depressing influence on germination.

The interesting observation was frequently made that under dry conditions such treatment, particularly with Ceresan, could produce as good or better germination than untreated cuttings planted under conditions of optimum soil moisture. For example, in one treatment, untreated cuttings in dry soil had a germination percentage figure of 46, which was raised to 92 by Ceresan treatment; under optimum conditions of soil moisture the respective figures were 86 and 95. (McMartin, 1945).

Experiments in Disinfecting the Ends Only of the Cuttings.

The experiments already quoted were all conducted by treating the whole cutting with the disinfectant; laboratory studies eventually showed, however, that the important matter was the application of the material to the cut ends only.

It was first demonstrated that by dipping the ends of the cuttings in the powder a very good control of pineapple disease could be obtained, a finding which was verified by a field trial (McMartin, 1944). Further, it was found that even with healthy cuttings an earlier and more vigorous root and shoot development followed the treatment of the cut surfaces. The means by which this is accomplished is not fully understood, but it raises the question of the effect on the root primordia and buds of the products of fermentation which occur naturally when even healthy sugarcane stalks are cut. Such stalks being rich in easily fermentable matter, a suitable medium is provided for the growth of micro-organisms occurring on the cut surfaces.

An experiment was therefore carried out to ascertain whether fermenting sugarcane tissue was toxic towards the roots and buds. For this purpose some healthy sugarcane stems were finely shredded and spread in a thin layer over the soil in pots in which cuttings of the same canes were planted; in addition, other pots had shredded cane mixed with the soil in the same proportions as that used to cover the surface. The germination was as follows:

Cuttings in soil alone	52%
Cuttings in soil plus shredded cane on the surface	8%
Cuttings in soil plus shredded cane mixed with the soil	2%

It is realised that this experiment is only of a preliminary nature, and by no means answers all the questions, but it does show that the presence of fresh sugarcane tissue in a state of fermentation can seriously affect the growth of the new organs, without even being in contact with them. It moreover lends support to the suggestion that apart altogether from disease con-

trol the application of a disinfectant to the cut surface of the cuttings may delay fermentation long enough to allow of a vigorous development of the young organs.

Another point of considerable interest was noted while conducting laboratory investigations, viz., that absorption of water by the cutting was apparently not necessary to initiate shoot and root development.

It appeared that sufficient moisture was present in the cutting to provide for this; in fact it was found that germination was possible simply by leaving the cuttings in the atmosphere in closed chambers without any water supply, and providing that the ends were disinfected, vigorous development took place, moisture meanwhile being *given off* by the cutting. (It has further been found that when cuttings are totally immersed in water no absorption takes place, and no growth occurs).

The development of cuttings in closed chambers (for which purpose large glass jars are used) has resulted in this method being used in our laboratory for evaluating the properties of various fungicides and for investigating various aspects of fungicidal treatment.

The main points brought out by such investigations may be summarised as follows:

1. The sugarcane cutting does not require to absorb moisture to initiate shoot and root development; it can lose moisture and grow.
2. To initiate growth under these conditions, however, disinfection of the cut ends must be resorted to; in most cases, without disinfection the cuttings rot.
3. Many substances are available for merely preventing fermentation, but some brands of fungicide in addition to being suitable disinfectants promote quicker root and shoot growth, i.e., they increase the rate of emergence. They appear indeed, to have a stimulating effect, although the term is used with some reserve.

FIELD EXPERIMENTS IN DISINFECTING THE ENDS OF THE CUTTINGS.

The laboratory experiments have been followed up by field trials. The disinfectants used so far have been as follows:

Organo-mercurial: Ceresan, Agrosan, Aretan, Verdasan, Abavit, Harvesan.

Organo-sulphur: Thiosan, Arasan, Tulisan, Nomersan.

Zinc: Vasco 4.

Copper: Cuprocide.

Quinone compound: Spergon, and Wettable Spergon.

It was found that disinfection could be achieved by the use of a solution of the fungicide where the nature of the material permitted it. This not only economised in material, as only low concentrations are necessary, e.g., from 0·5 to 1·0 per cent. for the organo-mercurial compounds, but rendered the dipping of the cuttings much simpler.

There is also evidence that any toxic effect which may be exhibited by some of these materials when applied as a complete covering to the cutting under wet soil conditions is minimised by this method.

So far the best materials have been found among the organo-mercurial group, as with these not only good disinfection is obtained but an acceleration of emergence is frequently encountered, thus producing a response of very considerable magnitude. (McMartin, 1945).

This aspect of the subject is illustrated by the following figures from a field experiment, in which cuttings were dug up and examined after three months growth.

Treatment.	Mortality of cuttings as percentage of those planted.	Mortality due to Pineapple disease as percentage of those planted.	Total number of shoots grown after three months (primary shoots and tillers).
Verdasan	2·7**	2·6	1831
Ceresan	5·4**	5·3	1831
Aretan	8·7**	6·3	3205**
Agrosan	9·4**	8·6	1856
Spergon	10·0*	9·6	1512
Cuprocide	11·0*	10·0	1555
Arasan	14·4**	14·0	1603
Thiosan	17·7*	19·3	1478
Nomersan	20·7*	19·6	1388
Tulisan	24·0	22·3	1298
Vasco 4	31·4	31·3	1291
Control	35·4	35·3	1493

(Each treatment had a plot of 50 4-budded cuttings replicated six times).

** Significantly better than controls at 99 : 1 odds.

* Significantly better than controls at 19 : 1 odds.

An obvious increased emergence rate was caused by Aretan, which was reflected in the population at three months.

An interesting observation was also made in examining the cuttings, bearing out laboratory studies. The lesser decay, in the cuttings that grew in the plots of the best treatments compared with cuttings from untreated plots, occurred with a corresponding increase in the number of shoots per cutting. Thus, with the treatment which produced the highest population, Aretan, the following figures were obtained.

Effect of Aretan on the decay of cuttings while growing: percentage of cuttings in each group.

	Control.	Aretan.
Cuttings decayed at end (cut) internodes only	26	56
Cuttings decayed at end internodes plus 1 inside internode	21	23
Cuttings decayed at end internodes plus 2 inside internodes	33	12
Cuttings decayed at end internodes plus 3 inside internodes (complete cutting decayed)	20	9

Effect of Aretan on the tillering of cuttings.

	Control.		Aretan.
Number of tillers per primary shoot where 1 bud grew per cutting	2·5	...	4·7
Number of tillers per primary shoot where 2 buds grew per cutting	3·7	...	4·0
Number of tillers per primary shoot where 3 buds grew per cutting	3·6	...	4·4
Number of tillers per primary shoot where 4 buds grew per cutting	4·2	...	4·1

Aretan treatment thus not only minimised decay of the sett, but produced on the average a more uniform and greater shoot population per cutting.

As a result of this experiment this fungicide has been used on a much larger scale.

Practical Applications.

It soon was appreciated that if dipping the ends only of the cuttings was sufficient, this technique became possible on the large scale. Accordingly several estates and planters were encouraged to interest themselves in the matter, and it is gratifying to be able to record that in a short while the value of such fungicidal treatment has been realised and the practice is spreading. Already, some of the larger estates who have tried it have decided to adopt it as a matter of routine.

The important feature, apart from disease control, is the ability to plant cane under conditions which normally would be considered too dry.

The last field experiment quoted was planted under extremely dry conditions, when growers were waiting for rain, yet by the means of a suitable treatment, a good stand of young shoots was obtained.

This has been actually achieved on the large scale by some growers, who have planted when they found it suitable, despite the fact that normally the soil conditions would have been considered unfavourable; some have even tried single stick planting, in winter, and produced a stand of cane which requires no filling in of blanks, an unlikely accomplishment previously.

With what extremes of soil condition this method will enable planting to be done remains one of the objects of future experimentation, but it is obvious that by the simple process of dipping the cuttings in a dilute solution of a suitable disinfection, used at the rate of about ¼lb. to ½lb. per acre, and costing little, a valuable method has been found of increasing sugarcane yields.

REFERENCES.

McMartin, A: "Pathological Conditions Affecting the Growth of the Sugar Cane Plant from Cuttings in Natal." *Proc. S.A. Sugar Tech. Assoc.*, **XI**: (1937).

McMartin, A.: "List of Diseases on Sugar Cane in Natal." *Proc. Int. Soc. Sugar Cane Tech.* **VI**: 214 (1938).

McMartin, A.: Pineapple Disease of Sugarcane Cuttings and its Control." *Proc. S.A. Sugar Tech. Assoc.* **XVIII**: (1944).

McMartin, A: "Fungicidal Treatments for Improving Sugar Cane Stands." *Proc. S.A. Sugar Tech. Assoc.* **XIX**: (1945).

FIG. 1

FIG 2

Fig. 1.—The two lines of sugar cane in the centre foreground were treated with an organo-mercurial fungicide prior to planting. On either side are two lines planted without treatment. This cane was planted in sandy soil in December and grew during very dry weather.

Fig. 2.—Sugar cane planted during favourable conditions, on good soil after rain. On the right the cuttings were disinfected with a soluble organo-mercurial fungicide, on the left they were untreated.

South African Journal of Science, *Vol. XLII, pp. 131-134, June, 1946.*

AN ENUMERATION OF FUNGI COLLECTED AT QUDENI FOREST RESERVE, ZULULAND, IN FEBRUARY, 1945

BY

Muriel W. Simpson

Transvaal Chamber of Mines Timber Research Laboratory,

AND

P. H. B. Talbot,

Division of Botany and Plant Pathology, Pretoria.

Read 2nd July, 1945.

The fungi enumerated in this paper were collected at the Qudeni Forest Reserve, Zululand, between the 13th and 20th February, 1945. In many cases the hosts were kindly determined by Professor A. W. Bayer, to whom, also, the authors are very much indebted for the invitation to accompany the Natal University College expedition.

To the best of our knowledge there are no published records of the fungi occurring at Qudeni, nor have systematic collections been previously made there, though a few isolated collections by M. W. Simpson and D. Weintroub, and by Father J. Gestner are filed in the Mycological Herbarium of the Department of Agriculture in Pretoria. This Herbarium also contains a few specimens from various other parts of Zululand, notable collectors being J. Medley Wood, W. Haygarth, Mrs. E. M. Laughton and W. G. Rump, but on the whole the forests of Zululand have never been submitted to an organised mycological survey.

In the present paper the poor representations of the *Agaricaceae* is due to the fact that many of the specimens deteriorated before reaching the laboratory and could not then be identified. No special search was made for fungi parasitic on leaves, so these are also poorly represented.

Most of the Basidiomycetes collected were growing on old stumps, logs and decayed twigs. In particular *Olea laurifolia, Olea sp., Xymalos monospora*, and the rotted wood of *Fagara capensis*, appeared most susceptible to attack. A number of the Basidiomycetes from Qudeni have been established in culture either from the fruiting body or from the rotted wood of the host, or from both these sources in the same specimen. Further work must be done to confirm the identity of some of these cultures.

During the collecting period, and the week preceding it, rain fell in the Qudeni area. There were frequent afternoon and night mists and the forest canopy was too dense to permit rapid drying of the vegetation and soil during the hours of sunlight.

The temperatures and relative humidity readings recorded within the forest were:—

February		Temp. °F.	R.H.%
14th,	12.45 hours	64	100
15th,	11.35 ,, ...	62	99
16th,	12.05 ,, ...	69	84
19th,	08.30 ,, ...	66	95
19th,	12.50 ,, ...	71	76
19th,	14.15 ,, ...	73	47

The numbers given below in brackets refer to the filing numbers of these fungi in the Department of Agriculture Mycological Herbarium in Pretoria. Any notes given as to the frequency of species refer only to the Qudeni area.

The authors wish to express their appreciation of the help given by Miss B. Louwrens in the identification of some of the fungi. Furthermore they are respectively indebted to the Transvaal Chamber of Mines and the Division of Botany and Plant Pathology for permission to take part in the expedition.

MYXOMYCETES.

Trichiaceae:

Arcyria denudata (L.) Wettstein
On dead *Olea* stumps .. .. (34932)

ASCOMYCETES.

SPHAERIALES.

Coryneliaceae:

Corynelia uberata Fries.
On *Podocarpus latifolius* leaves ... . (34933)
On *Podocarpus falcatus* leaves ... . (34934)
On *Podocarpus Henkelii* leaves ... ... (34935)
Very common on the above hosts especially on the forest margin.

Coryneliospora fructicola (Pat.) Fitzp.
On *Rapanea melanophleos* fruits ... ... (34936)

Xylariaceae:

Hypoxylon hypomiltum Mont.
On dead *Olea* sp. ... ... (34937)

Hypoxylon exutans. Cke.
On dead log ... ... (34938)

Hypoxylon glomeratum Cke.
On unidentified living tree ... ... (34939)
On dead log ... ... (34940)

Hypoxylon sp. (? immature *H. deustum* (Hoffm. ex Fr.) (Grev.)
Common on dead *Olea* sp. ... ... (34941)

Daldinia concentrica (Bolt.) Ces. et De Not.
On dead *Homalium* sp. Only one specimen seen ... (34942)

PEZIZALES.

Pezizaceae:

Patella scutellata (L) Morgan
On fallen *Olea*. Rare ... . (34943)

Helotiaceae:

Helotium sp.
Very common on dead twigs on ground. Host twigs possibly derived from *Rinorea natalensis* ... (34944)

HYPOCREALES.

Hypocreaceae:

Nectria sp. near *N. cinnabarina* (Tode) Fr.
On living *Kiggelaria africana* ... ... (34945)

Nectria sp.
Superimposed on a Mould on dead *Olea* ... ... (34946)
Megalonectria pseudotrichia (Schw.) Speg.
On felled Wattle just outside forest margin ... (34947)

DOTHIDIALES.

Dothidiaceae:
Elmerococcum peglerae (Pole Evans) Doidge.
On leaves of *Rapanea melanophleos.* ... ... (35004)

BASIDIOMYCETES.

TREMELLALES.

Tremellaceae:
Tremella mesenterica Retz.
Common on dead wood ... ... (34948)
Tremella sp.
On dead wood ... ... (34949)

AGARICALES.

Thelephoraceae:
Stereum lobatum (Kunze) Fr.
On dead wood. Common ... ... (34950)
Stereum Schomburgkii Berk.
On decayed log. Rare ... ... (34951)
Stereum affine Lev.
On rotten wood ... ... (34952)
Stereum hirsutum (Willd.) Fr.
On dead twigs and branches. Common (34953) (34956) (34957)
On dead Wattle stumps near Silutshana ... ... (34954)
Stereum hirsutum (Willd.) Fr. *Kalchbrenneri* forma.
On fallen *Olea* sp. ... ... (34955)

Clavariaceae:
Clavaria Kunzei Fr.
On ground and on roots of *Xymalos monospora.*
Two separate collections ... ... (34958) (34959)

Hydnaceae:
Hydnum sp.
On stump of Wattle tree ... ... (34960)
On living *Xymalos monospora* ... ... (34961) (34962)
Grammothele mappa (Berk.)
On dead stump. Very rare ... ... (34963)

Hydnaceae Imperfectae (?)
Ptychogaster sp.
On dead *Olea* stumps. Once found on living *Olea laurifolia* ... ... (35015)

Polyporaceae:
Poria rufitincta B. & C.
On dead wood ... ... (34964)
Poria contigua (Pers.) Fr.
On dead *Homalium* sp. ... ... (34965)
Poria sp.
On dead *Olea* ... ... (34966)
On dead *Fagara capensis* branches ... ... (35005)
On dead stumps and twigs on ground. Very common
(34967) (34968) (34969) (34970)
Polyporus virgatus B. & C.
On dead *Olea laurifolia* ... ... (34971)
On ground ... ... (34972)
Polyporus dictyopus Mont.
On dead bark ... ... (34973)
Polyporus ochroleucus Berk.
On unidentified living tree ... ... (34974)
Polystictus sanguineus (Linn.) Fr.
On living *Cassine* sp., dead *Olea* sp. and on dead *Homalium* sp. ... ... (34975)

Polystictus sp. near *P. pinsitus* Fr.
On dead branch of *Fagara capensis* ... ... (34976)
Polystictus sp.
On dead branch of *Fagara capensis* ... ... (34977)
Ganoderma applanatum (Pers.) Pat.
On decaying *Olea laurifolia*. Common ... ... (34978)
Ganoderma Emini P. Henn.
On ground, on roots of *Olea laurifolia*. Uncommon (34979)
Ganoderma rugosum (Blume et Nees) Bres.
On Wattle stumps outside forest margin, and at Silutshana ... ... (34980)
Fomes Robinsoniae (Murr.) Lloyd.
On living *Olea*. Fairly common ... ... (34981)
On dead stumps ... ... (34982)
Fomes rimosus (Berk) Cke.
On living *Olea*. On dead stump ... ... (34983)
Trametes cingulata Berk.
On dead stump ... ... (34984)
Trametes albotexta Lloyd.
Inside fallen hollow *Olea laurifolia* ... . (34985)
Trametes griseo-lilacina v.d. Bijl
On wooden fence post. S.A.P. camp, Qudeni ... (34986)
Trametes glabrescens (Berk.) Fr.
On dead stump ... ... (34987)
Trametes sp. near *T. varians* v.d. Bijl.
On fallen *Olea*. On twigs on ground. Very common.
(34988) (34989) (349990) (34991)
Trametes sp.
On live *Olea* ... ... (34992)
Lenzites palisoti Fr.
On living and dead *Olea laurifolia*. Common ... (34993)
Lenzites betulina Linn.
On forest stumps and Wattle logs ... ... (34994)
Hexagona Friesiana Speg.
On living *Olea laurifolia*. Rare ... ... (34995)
Laschia Friesiana P. Henn.
Very common on fallen twigs ... ... (34996)

Agaricaceae:
Hypholoma fasciculare (Huds.) Fr.
On dead stump. Rare ... ... (35014)
Crepidotus sp.
On dead wood ... ... (34997)
Schizophyllum commune Fr.
On dead Olea. Common on Wattle stumps near forest ... ... (34999)
Pleurotus sp.
On dead tree ... ... (35000)

LYCOPERDALES.

Phallaceae:
Dictyophora sp. in "Egg" stage
On ground among humus. Rare ... ... (34909)
Lycoperdaceae:
Lycoperdon sp. near *L. umbrinum* Pers.
On humus. Rare. ... ... (35002)
Nidulariaceae:
Cyathus olla (Batsch.) Pers.
On rotten stump and on dung in forest. Rare ... (35003)

South African Journal of Science, *Vol. XLII, pp. 135-136. June, 1946.*

A NOTE ON THE BIOLOGY OF *USTILAGO CYNODONTIS* (P. HENN) AND *USTILAGO BROMIVORA* (TUL), F. DE WALDH.

BY

C. Cohen,

University of the Witwatersrand.

Read 2nd July, 1945.

During preparation for class work, a distinct difference was noticed between the germination behaviour of spores of *U. cynodontis* and those of *U. bromivora*. The spores of *U. cynodontis* germinated readily, whenever collected or when tested at any time after storage; those of *U. bromivora* did not germinate at any time. This contradicts the statement made by Plowright (1889:84). Germination tests were made by mounting spores in a suitable medium on a cover slip, which was then inverted, loosely, over a glass ring on a slide. A drop of sterile distilled water was placed at the bottom of the cell. The preparation was then placed in a moist chamber. The germination medium was usually a mixture of 5% glucose and maltose. While this mixture had no perceptible advantage over distilled water, preference was given to it because of the better growth and spore production in an organic medium. Tests were usually carried out at room temperature. Germination in *U. cynodontis* occurred within 24 hours, with the production of large numbers of basidiospores and conidia. No difference in germination behaviour was observed between spores from young and those from old sori. Collections of sori were made throughout the season.

Field observations seemed to indicate that the first *Cynodon Dactylon* plants to be smutted with *U. cynodontis* would appear about the beginning of October, and that infected plants might appear from then until the end of summer. *Bromus unioloides* plants seem to show infection rather later, about the end of October, but large numbers of plants might not produce sori until later, depending on the kind of season. Heavy infections would occur together over a period of months, but probably not for as long a period as with *Cynodon*.

Material collected was stored in vials, with cotton wool stoppers, and then kept in a room, or left in a refrigerator. During the whole period of observation, there was no distinct difference between the *Cynodon* material stored in either way. After more than 15 months, germination was still profuse from both kinds of stored material.

While most tests were carried out at room temperature, the effect of higher temperature (35C), was tried on *U. bromivora*. This was not effective in inducing germination. Tests were made both in the light and dark, but light was not significant.

A number of chemical treatments were tried (Krietlow, 1943). Spores were washed in 95% ethyl alcohol for 30 seconds; spores were treated with chloroform for 5 minutes, then washed with 10% citric acid; spores were washed with chloroform for 45 seconds; spores were treated with 10% citric acid for two minutes; 0.02% malic and 0.02% citric acid were tried as mounting mediums; spores were treated with 95% alcohol for 2½ minutes. chloroform for 2½ minutes, washed with 10% citric acid for 5 minutes, then mounted in 0.02% citric or 0.02% malic acid. None or these treatments showed any beneficial effect when the spores were mounted for germination in the usual way. *U. cynodontis* spores treated with chloroform and citric acid as above, failed to germinate, but alcohol did not lead to a loss of viability. Mounted in malic or citric acid, germination seemed less profuse.

Other treatments were tried. 10 *Bromus* seeds that had been soaked for 48 hours were placed in 25 cc. sterile distilled water, and autoclaved at 10 lbs. for 30 minutes. Grass leaves, 10 cc. by volume, were autoclaved with 50ccs. water. The extract was then in both cases, used to test *U. bromivora* spores. No germination resulted.

Smutted *Bromus* material was placed in corked vials, with water in the vials, and left in a refrigerator. Tests were made periodically, but no positive results were obtained.

Finally, material that had been kept air dry for about 100 days, when placed in a corked vial with water for 24 hours, in a refrigerator, produce a small percentage of germinating spores. This percentage was increased by 24 hours drying over concentrated sulphuric acid, before mounting for a test, but after the cold soaking treatment.

At the same time, tests showed that not all the samples collected at different dates germinated, even under these conditions, so that it is clear that while the spores of *U. bromivora* require a period of maturation, and that this internal change is favourably influenced by alternate wetting and drying, not all spores, for some internal reason, are viable.

It is possible to see some correlation between the germination behaviour of the spores of these two smuts, and their behaviour under natural conditions.

REFERENCES.

KRIETLOW, K.: "*Ustilago striaeformis.*" *Phytopath.* **33**: S. 707-12 (1943).

PLOWRIGHT, C.: A Monograph of the British Uredineae and Ustilagineae. London (1889).

My thanks are due to Prof. J. Phillips, in whose Department this work was done, for his helpful criticism, and to Mr. P. Talbot, for his kindness in reading this paper and making some useful corrections.

South African Journal of Science, *Vol. XLII. pp. 137-138, June, 1946.*

A NOTE ON HOLLYHOCK RUST (*Puccinia malvacearum*, Mont). IN SOUTH AFRICA.

BY

C. Cohen,

University of the Witwatersrand.

Read 2nd July, 1945.

While preparing material for class work, the author became interested in the difficulty of regularly germinating teleutospores for the purpose of making slides for the promycelial stage.

It soon became clear that while there was a good chance of obtaining germination if the material was absolutely fresh, if the leaves bearing sori were allowed to dry for even 24 hours, for the purpose of making slides for the promycelial stage.

Method.—A suitable sorus was detached from the main body of the leaf, and partly broken up in a drop of sterile distilled water. The broken portions of the sorus, with any loose spores, were placed in a drop of distilled water on a cover slip, which was then inverted over a glass ring on a slide. A drop of distilled water was placed at the bottom of the cell. There was no adhesive substance between the cover slip and the glass ring. Germination usually occurred within 24 hours, and was definitely complete within 48 hours. Longer trial periods did not result in further germinations. The percentage varied from a very low figure to about a fifth or a third. On the whole, spores from the mass of the sorus seemed to germinate more readily than isolated spores, though detached spores were able to germinate.

The promycelial thread or epibasidium was usually clearly septate, but only rarely formed basidiospores or sporidia. Sometimes the epibasidium broke up into detached portions, referred to as conidia by Allen, and said by her to be due to the unnatural conditions of germination. Material when collected was stored either in a vial with a cotton wool plug in a refrigerator, or at room temperature

As mentioned above, material kept at room temperature soon lost its viability, but when stored at a low temperature, it remained viable for a week. Further, the percentage germination depended on the relative freshness of the spores on the living leaf, and these differences could be observed and correlated with the colour of the sorus.

Material which after storage had lost its ability to germinate, was treated with chemicals which might be expected to increase the permeability of the cell wall. Sori were washed in centrifuge

tubes for $2\frac{1}{2}$ minutes with 95% alcohol, then for $2\frac{1}{2}$ minutes with chloroform. Another set was washed with 10% citric acid. In no case did these treatments result in further germinations.

Material which had been kept for 45 days, was placed in corked vials with a small quantity of water at the bottom, and left in a refrigerator for 20 days. The material was tested intermittently, but was no longer viable. Material collected on 20th May, 1944, which was immediately placed in a corked vial with water at the bottom, showed germinating spores 50 days after the time of collection, although the spores had not shown any ability to germinate when tested in the usual way at first. In March, 1944, after a period of exceptionally wet weather, spores were found germinating in sori on the leaves. Again, in May, 1944, after a spell of cold weather, material was collected, which germinated readily when tested.

The following conclusions may therefore be drawn. The rust is capable of overwintering by means of sori which are more or less dormant on the leaves left at the base of the plant. Germination, and therefore, presumably, fresh infections may occur in late autumn, or middle winter, if conditions happen to be particularly suitable. Again, germination and infection can occur in early spring or through the summer, if the sporidia can reach suitable material. At the same time, many of the spores at this time may not be apparently capable of germinating.

The ability of the spores to germinate seems to be dependent on the state of the living leaf, and may be most intimately related to the water content. When the leaf is allowed to dry out, the spores soon die, and, as mentioned above, the state of the sorus is observable with the naked eye, and such observations are a fair index to the germinating capacity of the spores, in summer at least. During winter, after a period of exceptionally wet weather, spores were observed germinating in the sorus on the leaf. On the other hand, after a cold dry spell, spores were found to be exceptionally viable under normal test conditions.

In the laboratory, the spores remained alive if kept in a moist atmosphere, and at a low temperature, for 50 days, though storage at low temperature did not preserve them.

REFERENCE.

ALLEN, R.: "A cytological study of the teliospores, promycelia, and sporidia in *Puccinia malvacearum*." *Phytopath.* **23**: 7. 572-87 (1933).

I should like to thank Prof. J. Phillips, in whose Department this work was done; Dr. E. Doidge for her kindness in reading through this paper; and Miss S. Bilchik for allowing me to make use of material from her garden.

South African Journal of Science, *Vol. XLII, pp. 139-141, June, 1946.*

SCHOPENHAUER ON PLANT PHYSIOLOGY

BY

Dr. R. J. Jordan.

Read July 3rd, 1945.

Arthur Schopenhauer dealt with Plant Physiology in Chapter 23 of his main work " The World as Will and Idea ", he devoted to the subject a chapter of his treatise " On the Will in Nature ", and wrote about it in the second series of his " Parerga and Paralipomena". Though conceived before 1818, his works were brought up to date, in his opinion, down to 1860.

Schopenhauer regards the World as our Idea which the mind experiences as real and can mentally arrange into successive strata, ascending from inorganic nature through plants and animals up to man, and culminating in human genius. He derives Will from human experience but extends its meaning into that of a general life force and further into a general principle of existence and action. That force, he concludes, like gravitation, exists in animals and lower down the scale in plants and even in inorganic nature in different degrees.

Influenced by the double meaning of this word, he investigated the appearance of the Will in its more restricted sense throughout organic nature. There he distinguished again between plants and animals. In animals he found the power of perception and of increasing intellectual capacity up to man's reflective reason. In plants he postulated only the faculty of reaction to stimulants. Yet he searched throughout his life for any physiological phenomena which would manifest in plants a will still more closely analogous to the animal Will. Searching in this way amongst plants for every sign of spontaneity and will in its limited animal sense of deliberate choice and purposely directed action, Schopenhauer was particularly impressed by all movements or what to-day we call tropisms in plants as a possible sign of such animal will. He collected much evidence on this subject from books and periodicals during his lifetime, mostly from French sources. He quotes in detail Dutrochet on spontaneous movements of plants (1843), Cuvier on Geotropism, de Candolle on Phototropism and others, but he did not regard these symptoms as the expression of real animal will, and remained satisfied to the end with his original clear-cut division between plants and animals.

Extensive research has resulted in very much more material on this subject being available on the factual side. Investigations have been carried out into the mechanics and the chemical basis

of Tropisms, divided to-day into Geotropism, Phototropism, Chemotropism, Traumatropism, Haptotropism and Autotropism, the latter including nastic movements, of which Nyctinasty and Scismonasty already attracted Schopenhauer's particular attention, although he does not seem to have known the chemonastic movements of insectivorous plants. During the last century botanical resarch has been widely extended, and amoeboid or ciliary movements may possibly indicate the presence of animal will.

The amoeboid movements of the plasmodial stage of certain Slime Moulds (e.g. Physarus or Lycogala) were unknown to Schopenhauer as also were the movements of Flagellates and of all the waterborn Gametes of many lower plants, the complicated moving mechanics of the stomata guard cells, and the mechanism and effects of plant hormones; whilst the idea of electric potentials within plants would have seemed to him quite absurd. In the sphere of small aquatic creatures the dividing line between the animal and plant kingdoms becomes blurred, it ceases to exist altogether in the sphere of the very small forms of life. Furthermore we have become inreasingly conscious, since Schopenhauer, of the fact that all the higher forms of life, plants and animals, exist in the alternative rhythm of unicellular and multicellular phases, the biggest plants and largest animals undergoing the alternate forms of unicellular Gametes. To the latter, animal Will may be ascribed or denied, according to our definition of Will. They certainly have no will in the limited sense of animal will as experienced by man and the higher animals in the multicellular phase; they are rather influenced by stimuli. The same can be said of most unicellular animals. Some show the earliest traces of real will, i.e. deliberate choice, but we find exactly the same phenomena in some unicellular plants. Sherrington has discussed these facts in his book "Man on his Nature", but, of course, he could not solve the problem of where to start to speak of Will, or mind as he calls it.

Looking at all this new material, there seem to be two main lines or research which would have influenced Schopenhauer's ideas on Plant Physiology. The first of these lines leads to a special modification in the clear cut division of plant and animal Will. One may say that with regard to deliberate Will and activities, the two kingdoms resemble two overlapping circles. The tip of the animal circle's overlap is formed by very small unicellular creatures, while the tip of the plant circle's overlap is represented by the insectivorous plants. In between there is the great number of multicellular but primitive and often sessile aquatic animals like Sponges and members of the Order Coelenterata who all have either no special nervous tissues at all or only very primitive beginnings of such tissues which do not form a nervous system. Of all these creatures it can be said that they react upon stimuli as plants do, and a Will in the restricted animal sense cannot be postulated or assumed.

Compared with them, insectivorous plants, e g. of the Drosera type, exhibit a degree of purposeful activity that, when stimulated by external sources, comes very close to deliberate action, outwitting as it does members of advanced animal Phyla with well developed nervous centres.

The second line of modern research is intimately connected with the name of Sir J. C. Bose who has endeavoured to prove experimentally that plants show at least traces of a nervous system and that their reactions to stimulants correspond exactly to those of animals. Chemical and Physical stimulants are transmitted and transformed during transmission and Professor Bose went so far as to mention intellect expressly when discussing the behaviour of certain plants under the influence of repeated stimuli.

Combining these two main lines of research, nervous activities and the actions of insectivorous plants (though no such special research has yet come to my knowledge), true animal Will, e.g., in Drosera could be postulated without undue boldness. As far as scientifically investigated facts go, results seem to show that there is no " breach of continuity " (Bose) between the different forms of life and even between the organic and the inorganic. This result would strengthen Schopenhauer's world system in its great outline, while at the same time it would obliterate once and for all the scholastic concept of strict partitions.

Simultaneously with this new scientific outlook, our ideas, from the philosophical point of view, as to the values of human and animal will and of complication in general have changed since Schopenhauer. Increased knowledge of all natural phenomena around us has shown that greater complication often goes with decreased stability and involves a more precarious equilibrium. Thus, the animal will as compared with the plant's activities, while perhaps higher in complication, appears otherwise different rather than higher, particularly so when the qualities of strength, balance, endurance and perseverance are emphasised. Furthermore, all animal life depends upon plants and could even be called a function of plant life. Consequently we are less inclined, to-day, to search for manifestations of animal will in plants as something higher, least of all where the main line of philosophical deduction does not warrant such endeavours. It is possible to think that this new approach would have appealed very much to Arthur Schopenhauer, the first modern philosopher to include the realm of plants within his world system.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XLII, pp. 142-143, June, 1946.*

PRELIMINARY ACCOUNT OF INVESTIGATION INTO THE GERMINATION OF SEEDS OF *CYNODON DACTYLON*

BY

C. WEINBRENN,

Department of Botany, University of the Witwatersrand.

Read 2nd July, 1945.

This investigation was carried out with a view to determining the practical possibilities of establishing aerodrome surfaces from seed, instead of, as formerly, by roots and stolons. The elimination of the tedious and expensive method of planting roots by hand would result in a considerable reduction of costs.

Indigenous *Cynodon dactylon* has been found to be suitable for the purpose of surfacing aerodromes on account of its toughness, drought resistance, quick-spreading and hard-wearing qualities.

Seeds of *Cynodon dactylon* were collected from natural veld near various aerodromes and included Nigel, Randfontein, Germiston, Benoni, Palmietfontein, Potchefstroom, Baragwanath, Poortje Nigel and Kimberley strains. Germination percentages, optimum conditions for germination and methods of expediting and stimulating germination were studied.

In this paper the term seed has been used to refer to the caryopsis with its investing pales. The criterion for germination was taken to be the first appearance of the plumule.

Previous investigations on seeds collected from Benoni, Germiston, Palmietfontein and Randfontein aerodromes, carried out in the Department of Botany of this University showed that alternating temperatures, maximum 40°C., minimum 8°C.—12°C., gave high germination percentages, while constant temperatures at 27°C. and 35°C. resulted in practically no germination. The essential conditions for the germination of these seeds were (i) a suitable alternation of temperatures, (ii) sufficient moisture. Seeds allowed to dry completely for one, two and four hours respectively after the first germination occurred, showed progressively lower total germination percentages. Suitable alternation of temperatures occurs naturally in the field. Planting at the time of spring rains would ensure an adequate supply of moisture, otherwise watering becomes necessary to stimulate germination.

Germination percentages for seeds collected from the various aerodromes and germinated under favourable conditions were as follows:—

86%—91%	...	Benoni.
85%—98%	...	Germiston.
67%—76%	...	Palmietfontein.
± 79%	...	Kimberley.
± 76%	...	Vereeniging.
72%—85%	...	Baragwanath.
78%—85%	...	Poortje Nigel.
± 80%	...	Potchefstroom.

Pre-soaking was found to be beneficial to germination. Pre-soaked seeds in general gave higher total germination percentages and reached their peak period of germination sooner than dry seeds. Prolonged soaking, i.e. soaking for periods from one to four days, did not injure the seeds, but was in fact advantageous, the optimum period of soaking being about three days.

Methods of expediting germination were tried, including the effects of growth-promoting substances such as rootone and indole-acetic acid; passing seed through the alimentary canals of sheep; chilling; alternately freezing and thawing; composting. Some of these experiments did not give conclusive results, so they are being repeated. Composting followed by pre-soaking before germination proved to be the most satisfactory means of expediting germination. Two lots of seed were scattered over the surface of mature compost and covered respectively with 1in. and 2in. of compost, which was watered every alternate day. Sets of 100 seeds were put to germinate at a window bench after periods of six and eight days. The germination of the treated seeds was expedited by three to four days.

Experiments have indicated that seeds stored in compost for as long as four months have accelerated germination.

Seeds from various aerodromes were germinated in the field in rows 3ft. long and 1ft. apart on moist soil. Most of them germinated well and established good cover when planted at the rate of 20lb. per acre, i.e. 1·87 grams per row. Those seeds which showed higher germination in the laboratory at window benches, gave correspondingly better results in the field than those which gave lower germination percentages. Germination in the laboratory therefore proved a reliable indication of the germination potentialities under favourable conditions in the field.

From germination experiments with the seed of *Cynodon dactylon*, it is considered that they give sufficiently high total germination percentages to warrant the substitution of seeding for root and stolon planting in providing surfaces for aerodromes.

South African Journal of Science, *Vol XLII, pp. 144-146, June, 1946.*

CHROMOSOME STUDIES IN CYNODON

BY

Ruth Hurcombe,

Botany Department, University of the Witwatersrand.

Read 3rd July, 1945.

Since attempts to classify the species and numerous strains of the genus *Cynodon* on a morphological or anatomical basis have so far proved unsatisfactory, it was hoped that a cytological study of the material would assist in solving this taxonomic problem. It was also thought that the high degree of variability and sterility might in some strains be traced to some cytological abnormality. The Bradley strain (*Cynodon Bradleyi*, Stent.) was chosen for initial study because it is one of the most popular fine-leaved forms of *Cynodon*, and because of its low fertility. So far attention has been focused on the selection of suitable cytological methods which could later be applied to other species and strains of *Cynodon.*

Materials and Methods.

The " Bradley grass " material was collected from a lawn in the University grounds. Anthers were used for the study of the meiotic divisions, while secondary roots were selected as the most promising material for the examination of the somatic divisions. The pollen mother cells and the cells of the root tip were studied in both squash and microtome preparations.

The temporary acetocarmine squash technique afforded a rapid and effective method of obtaining clear chromosome counts in pollen mother cells (see Figs. 1 and 2). Attempts to make these temporary preparations permanent by McClintock's method were unsuccessful because the pollen mother cells did not adhere to the slide, and because the cells shrank considerably during the process. Various modifications of McClintock's method were tried in order to prevent shrinkage and loss of material, but none of these met with much success.

The squash method was completely ineffective with root tip material as the chromosomes in the cells did not absorb the strain, and the cells did not separate on squashing.

The paraffin method, however, proved most successful with root tip material. Careful attention was given to the choice of suitable fixatives and stains. Very good results were obtained after fixation in Navashin's fluid (old formula) and in Le Cour's

2BE fluid. No shrinkage occurred and the chromosomes showed clearly against a background of colourless cytoplasm. After fixation in Craf's fluid, Lewitsky's fluid, Carnoy's 3:1, Chamberlain's chrom-acetic, and Bouin's picroformol-acetic, the cytoplasm was so darkly stained and the chromosomes so poorly defined that it was impossible to make a chromosome count; in the case of all these fixatives with the exception of Lewitsky's the chromosomes were swollen and clumped together. Sections were stained with Heidenhain's haematoxylin, crystal violet, and the Feulgen nucleal stain, all of which gave good results. (See Figs. 3-5).

RESULTS.

It was established that the gametic chromosome number of the Bradley strain is 9 and the somatic number is 18. This number differs from those given by other scientific workers. Avdulow (1) counted 36 chromosomes in the root cells of *Cynodon dactylon*, and maintains that the basic number of the genus is 9. As the chromosomes number of the Bradley strain agrees with Avdulow's basic number, it would appear that Avdulow studied a polyploid form. Hunter (2) records a diploid number of 30 for *Cynodon dactylon* and considers the basic number of the genus to be 10.

Throughout microsporogenesis, chromosome behaviour appeared normal. Lagging of one or two pairs of chromosomes was occasionally observed in the anaphase of the heterotype, but the chromosomes did not lag sufficiently to allow any possibility of their being excluded from the daughter nuclei.

As the chromosome number, as well as the behaviour of the chromosomes during the maturation divisions in the anther, is normal, it appears that chromosomal irregularities during microsporogenesis are not responsible for sterility in the Bradley strain.

Whereas the chromosomes in the pollen mother cells were all oblong or pyriform in shape and differed only slightly in size, the chromosomes in a single root cell varied in length from one to two microns, and were rod-shaped, V-shaped, kidney-shaped or club-shaped structures. When the individual chromosomes of a somatic complement were arranged in homologous pairs, these pairs fell naturally into three groups: group I consisted of 5 pairs of kidney-shaped or V-shaped chromosomes; group II consisted of 1 pair of thin, long, club-shaped or dumb-bell-shaped chromosomes; group III consisted of 3 pairs of pyriform or rod-shaped chromosomes. It was interesting to note that the shape and thickness of the chromosomes differed slightly according to the stain used. After haematoxylin stain the chromosomes were thick with a distinct outline. In crystal violet preparations the chromosomes were thinner but owing to the transparency of the stain did not have a clear outline. After Feulgen staining the chromosomes were thinner than after haematoxylin or crystal violet.

None of the finer details of structure was observed in the root chromosomes. This may be due to the fact that the chromosomes were very small and that with the lenses available resolution of such details was not possible. It is also possible that other fixatives, or modifications of the fixatives used, might reveal the spiral structure of the chromosomes, the position of fibre-attachments, and the presence of constrictions and satellites.

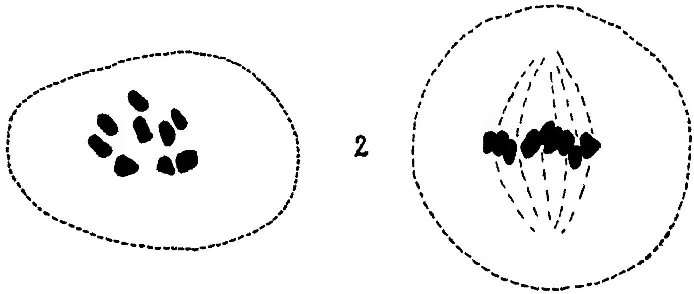
This cytological investigation of *Cynodon* is still in progress. The methods evolved for the study of the Bradley strain are being applied to five other common *Cynodon* strains, namely: Florida, Magennis, Royal Cape, Hall's selection and Nigel, in order to classify the strains on a possible cytological basis.

LITERATURE CITED.

(1) Avdulow, N. P.: "Karyo-systematische Untersuchung der Familie Gramineen." *43rd supplement to the Bulletin of Applied Botany, of Genetics and Plantbreeding.* (1931).

(2) Hunter, A. W. S.: "A Karyosystematic Investigation in the Gramineae." *Canad. J. of Research*, v. II (1934).

1 2



Polar view Equatorial view

(4/5¾) 900 X

Views of first metaphase in pollen-mother cells

Temporary aceto-carmine squash preparations

3 4 5

Feulgen stain Navashin fixative — Crystal violet stain Navashin fixative — Haematoxylin stain Navashin fixative

(4/5¾) 1500X

Polar views of metaphases during root mitosis

South African Journal of Science, *Vol. XLII, pp. 147-153, June, 1946.*

A CRITICAL STUDY OF THE TORSION BALANCE OF MEASURING TRANSPIRATION

BY

Dr. H. Weinmann and M. le Roux,
Botanical Department, University of the Witwatersrand.

Read 3rd July, 1945.

The torsion balance has been used in the past by a number of workers for the determination of the rate of transpiration. The essential feature of this method is the determination of the water loss of detached leaves during the first few minutes after they have been removed from the plant. Leick (1939), who gives an extensive bibliography of the subject, considers the method the most suitable one for ecological purposes but admits that it may fail in certain instances. In South Africa the method has been used by Mes and Aymer-Ainslie (1935), Irving (1940), Henrici (1940 and 1942), and Brueckner (1944).

From the fact that the rate of water loss from the severed leaf or shoot usually remains constant for a few minutes after cutting, the conclusion has been drawn that water loss determined in this way corresponds to the true transpiration rate of the intact plant. Very little work, however, has been done to prove the soundness of this assumption. and at least a number of observations are on record in which the rate of water loss of the cut plant has been shown to change immediately or almost immediately after severing.

The object of this investigation was to compare the transpiration rate of intact plants with that of severed plants by making these determinations in immediate succession on the same plant, and under comparable atmospheric conditions.

Method.—Plants of barley, Algerian oats, maize (variety Hickory King), wheat (variety Bedlam), and tall fescue (*Festuca elatior, L.*) were grown from seed in small glass vessels, 1.5in. high 0.7in. in diameter and filled with river sand.

The transpiration experiments were carried out when the plants had reached an age of two to four weeks. For the determination of the transpiration rate of the intact plants the soil surface in the vessels was covered with olive oil of best quality. The vessel was then suspended from the torsion balance and readings were taken every minute for a period of three minutes. The results of separate tests carried out at frequent intervals showed that no evaporation took place from the moist soil

surface in the vessels after the oil had been applied, and that the oil itself did not change in weight as a result of possible absorption or loss of moisture.

After the third reading had been taken the plant was cut off below the level of the oil. The cut end was, therefore, automatically sealed after severing. The plant was immediately suspended from the balance, and readings were taken as before. The torsion balance used was an improved (1939) model, manufactured by Hartman and Braun of Frankfurt am Main. All determinations were made in the laboratory with environmental conditions as constant as possible. Approximately forty pairs of experiments were carried out with each of the five species. Some of the experiments with each species were conducted on sunny days in direct sunlight, others in the shade, and some in indirect sunlight on overcast days.

Simultaneously with the transpiration measurements minute temperature and atmometer readings were taken. For the latter purpose a special micro-atmometer was set up. A white atmometer bulb was attached to a Ganong's potometer by means of rubber stoppers and glass tubing. This allowed the determination of the evaporating power of the air at intervals of one minute accurately to 0.01ml. Although the water loss determinations of the cut plants were always taken immediately after those of the intact plants, and no changes in temperature occurred, fluctuations in the atmometer readings were frequently observed. These may have been due to small changes in the light intensity, currents of air, or perhaps to faulty working of the atmometer itself.

Results.—Only those experiments will be considered here for which environmental conditions were definitely comparable, i.e., where atmometer readings during the second period (cut plants) did not vary more than ten per cent from those of the first period (intact plants). Further, it is not necessary to give the actual figures of water loss here. These have been recorded by le Roux (1945). It is merely intended to present a statistical analysis of the agreement in the water loss before and after severing the plant. For this purpose the total water loss for the three minutes before and after cutting was ascertained. The difference was expressed as a percentage of the water loss during the three minutes before cutting. This calculation was carried out for every experiment. Thus, if the transpiration rate before cutting amounted to 3.0 mg. per three minutes, and that after cutting to 4.0 mg., the difference was $\frac{(4-3) \times 100}{3} = +33$ per cent. The figures thus arrived at will be referred to as percentage discrepancy values in the following discussion.

The transpiration rate was found sometimes to increase, and sometimes to decrease, after cutting. The total number of experiments performed under comparable atmospheric conditions,

and the number of experiments in which an increase or decrease of water loss after severing of the plant took place are given in Table 1. Whether the transpiration decreased or increased after cutting, was, to a certain extent, apparently conditioned by external factors. When the experiments were carried out in direct sunlight a decrease in the transpiration rate resulted in most cases (namely, in 28 out of 35 experiments), while in indirect sunlight increases were as frequent as decreases.

TABLE I—Number of Experiments Performed Under Comparable Atmospheric Conditions.

Species:	Total.		Water Loss per 3 Minutes.	
			Cut > Intact.	Cut < Intact.
Barley . .	21	...	7	14
Maize . .	18	...	9	9
Oats . .	20	...	6	14
Wheat	17*	...	6	10
Fescue .. .	9	...	5	4
Total ..	85	...	33	51

* Perfect agreement in water loss before and after cutting in one experiment.

For a statistical analysis the percentage discrepancy values were classed in frequency groups, as indicated in Table II. This grouping was done irrespective of sign. For example, the first group (0·20 per cent.) includes all cases of decreases of the transpiration rate after cutting ranging from 0 to 20 per cent, as well as increases from 0 to 20 per cent. Since the number of experiments performed with the five individual species was not the same, the frequencies are expressed as percentages of the total number of experiments carried out with each species under comparable environmental conditions. An inspection of this table reveals that agreement in the transpiration rates of cut and uncut plants was, generally, very poor. In barley, maize, oats and fescue the transpiration rates before and after cutting

TABLE II—Frequency Distribution of Percentage Discrepancy Values. Expressed as Percentage of Total Number of Experiments.

Per cent. Discrepancy	0-20	20-40	40-60	60-80	80-100	> 100
Barley ...	9·5	33·3	19·1	4·8	14·3	19·0
Maize ...	11·1	33·3	16·7	33·3	5·6	0·0
Oats ..	10·0	5·0	25·0	30·0	15·0	15·0
Wheat ...	35·3	17·6	23·5	11·8	0·0	11·8
Fescue ..	11·1	22·2	22·2	33·4	0·0	11·1
Total ...	15·3	22·3	21·2	21·2	8·2	11·8

agreed only in approximately ten per cent. of the experiments within 20 per cent. The results were somewhat less disappointing with wheat, where in about one third of the experiments agreement within 20 per cent., was obtained. In maize, oats and fescue a relatively large proportion of the experiments gave deviations exceeding 60 per cent. In four of the species discrepancies exceeding 100 per cent. were relatively frequent (11 to 19 per cent.), and instances where the water loss of the cut plants approximated the transpiration rate of the intact plants were mere exceptions.

Table III shows the means, standard deviations, variability coefficients, and mean errors of the percentage discrepancy values, as calculated from the individual percentages discrepancy values of each species (again irrespective of sign). As will be seen,

TABLE III—Percentage Discrepancy Between Water Loss of Cut and Intact Plants.

Species	Barley	Maize	Oats	Wheat	Fescue
Mean	106·4	49·2	75·2	80·0	85·0
Standard Deviation ...	170·3	22·6	41·4	140·2	120·0
Variability Coefficient ...	161·2	45·9	55·0	175·2	141·2
Mean Error	37·0	5·4	9·2	34·2	40·0
Mean/Mean Error ...	2·9	9·1	8·2	2·3	2·1

the means range from 49 per cent. in maize to 106 per cent. in barley. The great variability of the results is reflected in the high values of the standard deviations and of the variability coefficients. The latter vary from 45.9 per cent. for maize to 175.2 per cent. for wheat. That the standard deviation values for barley, wheat and fescue exceeded in magnitude those of the means is due to the presence in these series of a number of discrepancies of several hundred per cent. As indicated by the ratios mean/mean error, the average percentage discrepancies for maize and oats are highly significant, those for the other three species at least probably significant.

Lastly, we have calculated the correlation coefficients for the two series of actual water loss determination in each species (mg. water loss per three minutes before and after cutting).

TABLE IV.—CORRELATION COEFFICIENTS.

For water loss in mg. per three minutes before and after cutting.

Barley	− 0.236
Maize	+ 0.355
Oats	− 0.185
Wheat	+ 0.572
Fesque	+ 0.052
All experiments	+ 0.319

Except for the figure for wheat, all correlation coefficients are definitely low. The correlation coefficients for barley and oats are even negative, indicating that in these plants the determination of the water loss after cutting tended to show high values where low values were prevailing before cutting, and vice versa. According to Fisher's statistical tables (1936) only the correlation coefficients for wheat and for the total number of experiments would be significant. From the practical point of view, however, even these correlation coefficients are too low to have any value for purposes of prediction. To support the claim that the determination of the water loss of a plant after having been severed from its roots represents a reliable measure of the transpiration rate of the intact plant, a positive correlation coefficient of, at least, 0.75 would be required.

In a number of experiments the period during which measurements were taken was extended to five minutes. In most instances large fluctuations of the water loss from minute to minute were observed in the plants after cutting. While in some experiments the rate of water loss per minute tended to increase after cutting, it decreased in others, or showed merely irregular fluctuations. In a few cases transpiration seemed to stop completely for a minute, after which it was resumed again. Only rarely did the water loss during the first minute after cutting agree with the transpiration rate of the intact plant during the last minute before cutting.

Discussion.—Most previous workers recorded decreases of the transpiration rate after cutting, presumably due to the lowering of the water reserves in the leaves and the possible closing of the stomata. That increases may also occur was first pointed out of Iwanoff (1928), who considered this to be due to a reduction in the water tension in the vessels following the process of cutting. Leick (1939) demonstrated that different species of plants may behave quite differently in this respect. In woody Karroo plants Henrici (1940) observed that the water loss remained constant for ten minutes or longer after cutting, and similar results were obtained by Brueckner (1944) with certain Natal thornveld plants. In detached leaves of *Themeda triandra*, on the other hand, the transpiration rate started decreasing during the third minute after severing (Mes and Aymer-Ainslie, 1935). Among previous investigators Pfleiderer (1934) appears to be the only one who attempted to ascertain whether the transpiration rate of the plant after cutting agrees with that of the intact plant immediately before cutting. Testing various herbaceous and woody species, Pfleiderer measured the transpiration rate of the potted plants by the ordinary weighing method, and immediately afterwards and under identical atmospheric conditions, that of the cut plants by means of the torsion balance. He found that in 34 such experiments the water loss of the plants three to five minutes after cutting averaged 98.9 per cent. of the value measured before

cutting. From this Pfleiderer concluded that the "average deviation" of the transpiration rate of the cut plants from that of the intact plants amounted to only − 1.1 per cent. This is, however, an entirely erroneous and misleading conclusion, based on the incorrect evaluation of numerical data. The apparently small "average deviation" of − 1.1 per cent. is merely due to the opposing effects of much larger positive and negative deviations, which ranged from − 23 to + 26 per cent. If calculated correctly (i.e., irrespective of sign) the true average deviation amounts to ten per cent. Ten minutes after cutting the true average deviation from the initial value amounted to 24 per cent. with maxima of 70 per cent. in individual cases, the majority representing decreases in the transpiration rate. Schartz (1931), studying the water relations of plants in Arizona, considered that the water loss from detached plant parts cannot be regarded as the normal transpiration rate of the plant.

There seems to be little doubt that the process of severing a part of the plant results in alterations in its physical condition which are bound to have decisive effects upon the metabolism of the affected organs. The exact nature of this interference is not known, and the response to such treatment may vary with the species as well as with environmental conditions. The experiments reported here were all carried out on relatively young and tender plants. Such plants may be particularly susceptible to the "shock" imparted to them by cutting, and may possibly react so rapidly that it is not possible to obtain reliable values of the true transpiration rate by means of the torsion balance. While far reaching generalisations should be avoided, it follows nevertheless that the uncritical use of this method may lead to doubtful and meaningless values. It would appear that considerably more work of a fundamental nature is required before transpiration values of detached leaves can be accepted as trustworthy.

Summary.

Plants of barley, maize, oats, wheat and tall fescue were grown in small vessels. Using a torsion balance the transpiration rate of the intact plants was determined, and immediately afterwards and under identical atmospheric conditions, that of the cut shoots.

Agreement in the rate of water loss for three minutes before and after cutting was poor. Only in approximately ten per cent. of the experiments with barley, maize, oats and fescue, and in 35 per cent. of the experiments with wheat did the transpiration rates agree within 20 per cent. The average discrepancies ranged from 49 per cent. in maize to 106 per cent. in barley.

The correlation coefficient for the actual water loss during the three minutes before and after cutting in all (85) experiments was + 0.319.

The results indicate that in the plants investigated the determination of the water loss from the cut plant cannot be regarded as a reliable index of the true transpiration rate of the intact plant.

ACKNOWLEDGEMENTS.

The writers desire to express their sincere thanks to Prefessor J. Phillips, Head of the Botanical Department of the Witwatersrand University, for his interest and for having made this research possible; and to Dr. A. E. H. Bleksley for valuable criticism.

REFERENCES.

BRUECKNER, A. E.: " Transpiration Studies of Some Natal Midlands Thornveld Trees." *This Journal*, **41**: 186-193 (1944).

FISHER, R. A.: "Statistical Methods for Research Workers." Sixth Ed. Oliver and Boyd, Edinburgh (1936).

HENRICI, M.: " The Transpiration of Different Plant Associations in South Africa. Part I—Transpiration of Karroo Bushes." Union of South Africa. Department of Agriculture and, Forestry Science Bulletin No. *185*. (Plant Industry Series No. 39) (1940).

HENRICI, M.: " Transpiration of Grasses in the Sour Mountain Grassveld of the Drakensberg in Comparison with the Water Loss of Indigenous Forests." *This Journal*, **39**: 155-163 (1942).

IRVING, M.: " A Study of the Effects of Eucalypts on the Soil, their Nutrient Requirements, and Transpiration." *This Journal*, **32**: 133-135 (1940).

IWANOFF, L. A.: ,, Zur Methodik der Transpirationsbestimmung am Standort." *Ber. d. Deutsch. Bot. Ges.* **46**: (306-310 (1928).

LEICK, E.: ,, Bestimmung der Transpiration und Evaporation mit Rücksicht auf die Bedürfnisse der Oekologie." Abderhalden's Handbuch der biologischen Arbeitsmethoden, Abt. XI, Teil 4, Heft 8 (Schluss); Lieferung 479 (1939).

LE ROUX, M.: " An Investigation into Various Aspects of the Water Relations of Certain Grasses." *Unpublished M.Sc. Thesis, University of the Witwatersrand* (1945).

MES, M. G., and AYMER-AINSLIE, K.M.: " Studies on the Water Relations of Grasses, 1. *Themeda Triandra, Forsk. This Journal*, **32**: 280-304 (1935).

PFLEIDERER, H.: ,, Kritische Untersuchungen zur Methodik der Transpirationsbestimmung an abgeschnittenen Sprossen." *Zeitschrift für Botanik*, **26**: 305-327 (1933/34).

SCHRATZ, E.: ,,Vergleichende Untersuchungen über den Wasserhaushalt von Pflanzen im Trockengebiete des südlichen Arizona." *Jahrbücher für wissenschaftliche Botanik*, **74**: 153-290 (1931).

South African Journal of Science, *Vol. XLII, pp. 154-156, June, 1946.*

THE SIGNIFICANCE OF *SCHIZOSACCHAROMYCES OVIS* IN FERMENTATION AND GAS PRODUCTION IN THE FORE-STOMACHS OF RUMINANT ANIMALS

BY

Dr. R. Clark,
Onderstepoort.

Read 4th July, 1945.

Introduction.—A large amount of gas is evolved during the fermentation of the ingesta in the fore-stomachs of ruminant animals. This consists mainly of carbon-dioxide (67%) and methane (26%) (Kleiber, Cole and Mead 1943), and is normally eliminated by absorption into the blood stream and subsequent expiration or by eructation. At times, however, the gas accumulates causing "bloat" or "hoven." This condition is most frequent when leguminous plants are fed, and its occurrence is a serious handicap to the use of these valuable nitrogenous feeds. On the other hand it must be remembered that gas production is an integral part of the process of fermentation which is essential to ruminant digestion. A study of the metabolism of the ruminal flora and fauna is, therefore, a prerequisite to the understanding of ruminant digestion both in health and in disease.

Quin (1943) described a pseudo-yeast (*Schizosacchromyces ovis*) which was found in large numbers in the ruminal ingesta of sheep when these animals were fed on lucerne. When the host animal had not fed for some twelve hours the contents of the pseudo-yeasts were clear and hyaline. If now a little glucose was added to such ingesta and the mixture incubated there was a rapid evolution of gas and the pseudo-yeast cells were found to be filled with glycogen which stained brown with iodine. Quin separated these organisms and showed that they were largely responsible for the gas formation.

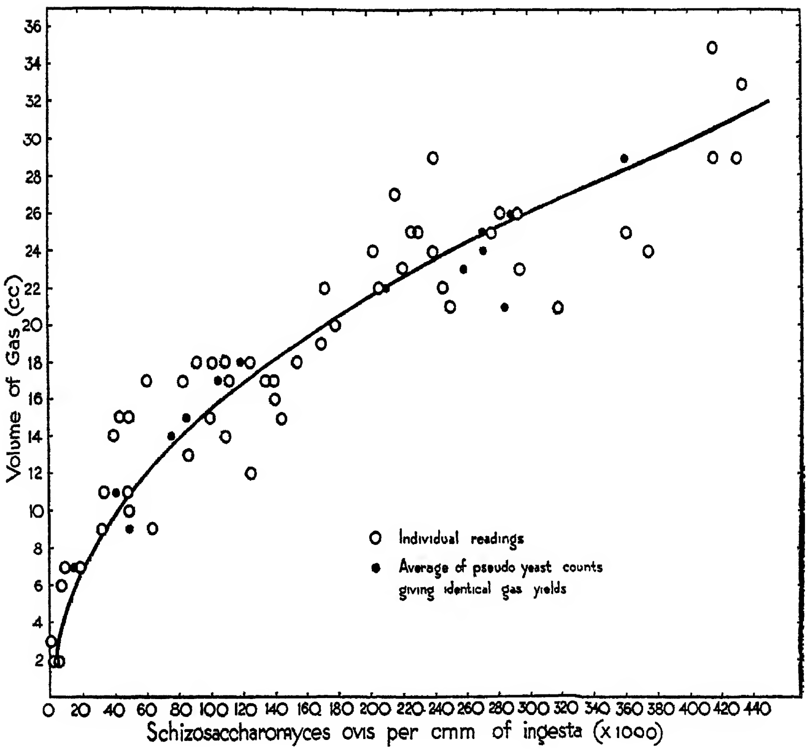
The object of the present paper is to report a correlation between the number of *Schizosaccharomyces ovis* present in ruminal ingesta and the amount of gas evolved from it after the addition of a standard quantity of glucose.

Method.—Five Merino sheep with permanent ruminal fistulae were used. Lucerne hay *ad lib* was exclusively fed throughout the experiment. From time to time samples of ruminal ingesta were taken 16 hours after a feed. The ingesta were squeezed through butter muslin and 50 cc. aliquots of

the fluid placed in Erlenmeyer flasks. Glucose (·04gm.) was added to each sample and the flasks were mechanically shaken in a water bath at 39°C. for 15 minutes. The volume of gas evolved during this time was recorded.

The flasks were then removed from the water bath and 50 cc. of 10% formalin added to each to kill and fix the organisms. After thorough shaking, one cc. of this mixture was added to 49 cc. of water and again one cc. of this dilution was mixed with an equal quantity of Lugol's iodine solution. The final dilution was, therefore, 1 in 200 of the original ingesta. The pseudo-yeasts were counted in a Burker-Turk blood counting chamber and the number per c.mm. of the original ingesta calculated. This figure was compared with the gas yield from the same sample. In all 56 pairs of such readings were obtained.

Results.—The results obtained are plotted on the graph reproduced below.



As will be seen from the graph there was a very high correlation between the number of *Schizosaccharomyces ovis* present and the volume of gas evolved. The curve is plotted to the for-

mula: Gas = 1·62 (Yeast) 0·49 which in terms of the logarithms of the variates yields a straight line with a correlation coefficient of 0·9692.

Conclusion.—This result would indicate that *Schizosaccharomyces ovis* plays a dominant role in the rapid evolution of gas in the fore-stomachs of runiments after the ingestion of lucerne and hence is an important factor in the pathogenesis of bloat on this feed.

Acknowledgements.—I have to thank Mr. D. van den Reyden for the statistical analysis of the results.

REFERENCES.

KLEIBER, M., COLE, H. H. and MEAD, S. W.: "Bloat in Cattle and Composition or Ruminal Gases." *Jl. Dairy Sci.* Vol. 26 (1) p. 929 (1943).

QUIN, J. I.: "Studies on the Alimentary Tract of Merino Sheep in South Africa." VII. "Fermentation in the fore-stomachs of sheep." *Onderstepoort Jl. Vet. Sci. and Animal Ind.* **18:** (1 and 2) p. 91 (1943).

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XLII, pp. 157-161, June, 1946.*

THE BIOLOGICAL ACTION OF BOTULINUS C. (LAMSIEKTE) TOXIN

BY

DR. J. I. QUIN,
Section of Physiology, Onderstepoort.

Read 3rd July, 1945.

Introduction.—Botulism in man and animals has been studied intensively especially from the bacteriological and immunological aspects with the result that a voluminous literature on this subject is already in existence.

In a comprehensive study on Lamsiekte in South Africa, Theiler and his associates were able to show that this is a characteristic form of botulism amongst farm animals and of widespread occurrence over large areas of South Africa. Carcass debris poisoned with botulinus toxin is greedily consumed by stock especially where the vegetation is deficient in essential phosphorus, and this may be the cause of severe losses unless timely preventive measures are undertaken. Although both the aetiology and symptomatology of botulism have been very fully discussed in the laterature, there is as yet no certainty concerning the action of the toxin on the various organ systems except that in the majority of cases it is associated with paralysis of certain voluntary muscles. According to Theiler the possibility exists that both the motor centres in the central nervous system as well as the terminal branches of the spinal nerves may be affected by the toxin. Apart from some venous engorgement of the brain, Cowdry and Nicholson were unable to detect any histological changes in the central nervous system, although it is admitted that this does not exclude the possibility of functional disturbance in that region. From investigations with botulinus A and B toxins, Dickson and Shevky maintain that the chief action is concentrated on the motor nerve terminals thus causing marked susceptibility to fatigue in certain groups of voluntary muscles. At the same time conduction in the parasympathetic division is blocked by the toxin.

Experimental Procedure.—In order to gain further information about the action of Lamsiekte toxin especially on skeletal muscle and on the motility of the digestive tract of animals, a series of experiments was conducted in which the toxin was either injected into animals and the symptoms noted or its effects studied on isolated tissues. For this purpose highly virulent crude botulinus toxin (type C) was kindly supplied by Dr. M. Sterne of the Bacteriological Section, Onderstepoort.

The following represents a summary of the main results achieved thus far:

1. Effects on Voluntary Muscular Action.

Following the injection of toxin into toads, white rats, rabbits and sheep in doses varying from 1cc. to 0·001 cc., a latent period lasting from several hours to several days is invariably noted during which no clinical changes whatever can be detected. Usually the first sign of illness is a sudden and rapidly progressive weakness in those muscles which normally show the highest degree of tone in the body, viz., the neck muscles responsible for extension of the head, muscles controlling deglutition, the tongue and closure of the jaws, muscles attached to the scapulae and responsible for suspending the thorax between the front limbs, and the extensors of the front and hind limbs. Irrespective of the site of the injection, e.g. either into the tip of the tail or intracerebrally, the spread of the muscular weakness is invariably from the head and neck backwards.

In the smaller laboratory animals locomotion during the early stages of the disease is maintained chiefly by the hind legs while the head and front quarters being in a drooping collapsed condition are helplessly pushed along the surface. Ultimately the whole body shows prostration except for the tail of the white rat which maintains tonus right up to the end.

2. Reflex Action.

All superficial reflexes including those from the skin associated with pain, extensor and flexor responses from the limbs, and corneal reflex are all maintained until the animals finally pass into coma. Again the responses elicited by the hind limbs are maintained longer than those from the front quarters. Repetition of stimuli, however, rapidly causes fatigue especially in the motor part of the reflex arc, as shown by inability to close the eyelids or to flex a limb. General sensation nevertheless remains acute despite progressive weakness in motor response.

Faradic stimulation of the radical and femoral nerves evokes definite response in the lower part of the limbs although of very limited duration, after which the muscles show complete refractoriness towards further stimulation.

Similar effects are noted in poisoned toads (*Xenopus laevis*) from which the gastrocnemius muscle and sciatic nerve have been isolated. Although single induction stimuli provoke apparently normal muscular twitches, both through stimulation of the nerve and of the muscle itself, repetition of such stimuli very soon fails to induce any further contraction. Moreover, there is no tendency towards contracture as frequently seen in fatigued amphibian muscle. On the contrary there is complete relaxation and loss of tone after a few induction shocks. Weak

faradization of such poisoned muscles results in tetanic contraction which is similarly of very short duration. This is rapidly followed by complete relaxation and refractoriness.

Experiments thus far conducted afford clear evidence that the muscular symptoms noted in Lamsiekte are due to a progressive loss in muscular tone associated with muscular weakness and increased susceptibility to fatigue. Conversely there is no evidence of any functional derangement either in the motor areas of the cerebrum or in the motor tracts of the spinal cord which in turn would result in a true paralysis of the muscles. Instead of this the effect of botulinus C toxin somewhat resembles that of a poison such as curare which acts peripherally on the neuromuscular endplates, except that in botilinus poisoning there is always a definite latent period before muscular symptoms are developed, while with curare the effect is more prompt. Moreover, in curare poisoning the muscle is still capable of direct stimulation whereas in botulinus poisoning this reaction of the muscle is rapidly lost. Whether this fatigue in Lamsiekte is associated with a derangement in muscular metabolism as occasioned by a poison such as monoiodoacetic acid presents an interesting biochemical problem.

3. Effect on the Heart.

Cardiac acceleration is an early symptom of botulism, frequently detectable even before the skeletal muscles are affected. This, however, is associated with a progressively increasing arrhythmia in which the heart rate may be doubled, e.g. from 60 to 120 per minute. At times this wide fluctuation may be noted within a single minute. Thus in the case of a sheep in which the heart beat was counted continuously over a period of five minutes, it was found that the cardiac rhythm was changed no less than nine times, the periods of acceleration lasting on an average of 15 seconds as against 8 seconds during which it was decelerated. According to the view expressed by Dickson and Shevky this effect on the heart may be due to an unstable and intermittent blocking of the vagus by the toxin. Alternatively it can be explained as the onset of fatigue in the myocardium similar to that detected in skeletal muscle. Examination of the heart after death reveals acute distension of both right chambers while the left auricle is frequently found in full systolic contraction with sub-epicardial and sub-endocardial haemorrhages visible in one or both of the ventricles. Taken together, the effects of the toxin strongly suggest those of an active cardiac poison which may be considered the main lethal factor in Lamsiekte.

4. Influence on Respiration.

Weakness in the muscles of the forequarters soon spreads to the intercostal muscles, in which the respiratory movements

become progressively weaker. This is accompanied by a change from costoabdominal to purely abdominal breathing whereby the activity of the diaphragm outlasts that of the intercostal muscles by a considerable margin. This is very clearly visible in the white rat which, although severely affected by the toxin otherwise, tenaciously maintains a slow and deep diaphragmatic breathing. The fact that a considerable number of rats ultimately recover after a prolonged and precarious struggle, may be due to their ability to maintain diaphragmatic respiration.

Apart from this characteristically deep abdominal breathing in all animals studied, no signs of accelerated respiration or dyspnoeic struggling are to be detected despite a progressively severe cyanosis during the final stages of intoxication. At death the diaphragm is usually found in a completely relaxed condition while the lungs are severely congested and frequently oedematous.

5. Action on the Blood and Blood Vessels.

By puncturing the skin of the ears of white rabbits with a sharp needle, minute traces of toxin can be introduced into the subcutaneous tissues. In such animals the peripheral blood vessels reveal no deviation whatsoever from the normal vasomotor changes, i.e. there is no local reactive hyperaemia or inflammation. Nevertheless, such animals contract typical Lamsiekte thus indicating that fatal amounts of toxin can be absorbed from these puncture wounds. At death there is marked venous engorgement of all the viscera and of the splanchnic vessels due to the collapse of the heart.

The blood itself shows marked cyanosis towards the end. Morevover, there is a distinct haemoconcentration with haema tocrit values rising by 10% or more. This forms part of a general dehydration of body tissues which is due largely to the inability of animals to swallow food and water, and to the loss of saliva from the mouth.

6. Digestive Tract and Secretion.

Contrary to the effects seen in skeletal muscle, the plain muscle of the digestive tract, the gall bladder and urinary bladder suffers no visible impairment in its motility. Thus strong rumen movements are maintained in the majority of sheep, active peristalsis in the intestines of rabbits and normal defaecation except in protracted chronic cases where excessive dehydration supervenes. Likewise the urinary bladder is repeatedly emptied without difficulty.

By suspending duodenal strips in a Dale bath in the presence of high concentrations of toxin, it is found that the normal rhythmic contractions are in no way interfered with. From various observations made there is evidence that neither plain muscle itself, nor the autonomic system which controls its activity is seriously affected by the toxin.

As Lamsiekte animals experience great difficulty in swallowing, a characteristic symptom noted especially in cattle and sheep is the profuse and continued dribbling of saliva from the mouth. In ruminants salivary secretion is a continuous process normally, even when they are not feeding. Consequently if this flow of saliva cannot be swallowed it is lost from the mouth. In the case of a sheep in which the saliva was caught up this amounted to 600 cc. secreted in 12 hours. The continued loss of saliva, together with the inability to drink water, results in a progressive dehydration of the tissues and a rapid wasting away. In an attempt to mobilise all water reserves in the body, the contents in the fore-stomachs as well as in the small and large intestines are thoroughly dehydrated. The ingesta in the rumen are rolled into hard dry balls thus causing a dehydration impaction and not a paralytic impaction as commonly assumed. This dehydration with impaction is very frequently seen especially in the more chronic cases of Lamsiekte and seriously aggravates the condition. Moreover, with the loss of saliva there is a constant drainage on the alkali reserves of the body and a consequent disturbance in the acid-base equilibrium tending towards acidosis. Diuresis which is frequently noticeable contributes towards further dehydration.

Concerning the secretion not only of saliva but also of digestive juices from the stomach and intestines including that of mucus, there is no evidence whatever that these are inhibited by the toxin.

REFERENCES:

Cowdry, E. V. and Nicholson, F. M.: "An Historical Study of the Central Nervous System in Experimental Botulinus Poisoning." *Journal Exp. Med.* **39**: 827-836 (1924).

Dickson, E. C. and Shevky, R.: "Botulism—Studies on the Manner in which the Toxin of Clostridium Botulinum Acts upon the Body, 1. The Effect upon the Autonomic Nervous System." *Journal Exp. Med.* **37**: 711-731 (1923).

Dickson, E. C. and Shevky, R.: "Botulism—Studies on the Manner in which Toxin of Clostridium Botulism Acts upon the Body II. The Effect upon the Voluntary Nervous System." *Journal Exp. Med.* **38**: 327-346 (1923).

Theiler, A.: "Lamsiekte (Parabotulism) in Cattle in South Africa." *11th and 12th Rep. Dir. Vet. Educ. and Research,* Part 2, pp. 821-1361 (1927).

South African Journal of Science, *Vol. XLII, pp. 162-171, June, 1946.*

PROBLEMS OF GAME CONSERVATION IN SOUTHERN AFRICA

BY

Dr. Gilles de Kock,
Onderstepoort Veterinary Laboratory.

Read 3rd July, 1945.

Game conservation in South Africa has frequently been discussed at meetings of scientific societies, in scientific journals and books, in the press and at farmers meetings. Papers have appeared in the South African Journal of Science (e.g., R. Bigalke, 1943). Reference must be made to the monumental works of Colonel J. Stevenson-Hamilton, who has probably done more for the preservation of game in the Transvaal than anyone else. In his book " South African Eden," the following passage is very significant: " it will be seen therefore that President Kruger, the leader of his country was also the first to recognise the necessity of preserving its wild life permanently and that so long ago as 1884 he attempted to get his view adopted."

As a result of a resolution passed at the general meeting of the South African Association for the Advancement of Science in 1943, the Council submitted in May, 1944, a memorandum to the Government on the National Parks, Game Reserves and Botanical Reserves in the Union. In this memorandum Council recommended: " that the time has come for the co-ordination of the work of all bodies controlling National Parks, Game Reserves and Botanical Reserves. To this end it is recommended that Council requests the Minister of Lands to convene a meeting of all interests concerned, to consider how best to achieve this co-ordination. It is further recommended that adequate scientific representation be provided for any central organisation that may be set up."

The following passages from the outstanding Report of the Committee on Nature Conservation, etc., deserve consideration.

"The existing methods of preservation are not enough, valuable as they have been in the past, and some comprehensive and systematic plan must be adopted. The wild life of our country has always been and still is a vital source of pleasure and refreshment to large sections of the community. It demands our immediate attention as in the inevitable changes of the next few decades much of what remains will be seriously threatened."

"The claims of agriculture and forestry will play a prominent part in post-war development. Demands are being made for more land for Native Reserves, and soil erosion is exerting its devastating influence on what at one time appeared to be fertile regions of South Africa."

"A survey of the whole problem needs immediate and careful attention so that steps can be taken to conserve under proper control so much of our wild animal life as is reasonable and practical for our mental recreation and for the enjoyment of its beauty and interest and for purposes of study and education."

This brief consideration will confine itself to some of the problems of conservation of game animals, although it should be stressed "that the conservation of vegetation, the natural covering is the ultimate basis directly or indirectly of all animal life. Consideration will have to be given to safeguard and maintain tracts of the fast disappearing wild country and to preserve unspoiled and free natural habitats of plant communities to develop their own natural vegetation under expert management and control."

Compromise will be necessary in the planning not only between possible economic uses, but also between these and the preservation of natural beauty. In respect to the limits of Nature Reserves topographical conditions should be given greater consideration. Existing boundaries in some of the Reserves deprives game of important grazing areas, especially in times of drought.

What is furthermore required is continuous study of the distribution, density, habits of each species and their inter-relationships, the progressive disappearance of species from many of their old habitats, etc. The ecology study and the scientific aspect cannot be sufficiently stressed. It will not only advance an important branch of biological science, but it will materially assist when such ecological knowledge gained by Research and application is applied to management and control. A good deal of knowledge has been gained during the past quarter of a century and this is being steadily increased as new studies are undertaken.

Colonel Stevenson-Hamilton in his address on wild life ecology in 1941 refers to the fluctuations of certain species of game animals and he is of opinion that the life history of every species in a wild state proceeds, not in a straight line, but in a series of curves and finally he states that nature has her own wise methods of adjustment. Scientific investigation is highly desired to understand this complex tangle of motives, feelings, habits, activities, environment, etc., affecting density and distribution of our higher vertebrate fauna. This knowledge is necessary to protect rare or specially interesting species of animals or plants which are in danger of becoming rare or extinct. The whole problem of nature conservation must be viewed against the human and social background. Do not let us adopt the policy of " letting nature alone."

Decrease in the population of predatorial species (e.g., carnivores, birds, and mammals) may lead to a great increase of small rodents, e.g., mice, voles, rats, rabbits and recently, in certain areas in the Union, *Procavia capensis* (dassies), (communication by Thomas, 1945), the principal food of predators, with

resulting serious loss and widespread damage to agriculture and crops. Game preservation may lead to high local density of certain species pressing hardly on agriculture and excessive density may result in serious epidemic disease (e.g., grouse disease).

Shooting and hunting interests in the Union of South Africa should submit to a great deal of curtailment of the privileges enjoyed in the past. This is a matter receiving the consideration of a Commission appointed by the Transvaal Provincial Council.

The importance of disease in wild animals has been stressed by Neitz and Thomas (1938). Very interesting tables were given in which are listed the disease and disease-producing organisms which the larger and commoner wild animals are known to harbour or to which they are known to be susceptible. In a paper "Wild animals as carriers of Infection" De Kock (1938), refers to the important part they may play as reservoir host in the propagation and dissemination of disease to man and domesticated animals, e.g., trypanasomiasis, rabies, malignant catarrhal fever (snotsiekte), swine fever, rickettsiosis, tuberculosis, foot and mouth disease, rinderpest, psittacosis, etc.

Hudson (1944), commenting on the role of the reservoir host in tropical disease is of opinion that in civilised and temperate zones none of these form a grave menace to our national health, whereas in tropical medicine the animal reservoir plays a prime role. There is, however, a lack of precise information in this field. In the first place there is the lack of knowledge of the fundamental biology of the animal reservoir host and facilities for research in this tropical field have been scanty. There is an intricate web of animal and insect life in a physical environment of extraordinary complexity and variability which needs elucidation.

In respect of a few of these tropical diseases of domestic animals, some reference should be made, because it is believed that game plays a part in their dissemination and recrudescences in Southern Africa. The problem will be considered from the wider "Southern African" point of view, because in some of these diseases neighbouring states are involved in their spread, because game that migrate do not recognise international boundaries.

In view of the recrudescences of foot and mouth disease in Southern Africa since the initial outbreak in 1931 in Southern Rhodesia, there is a strong feeling that this disease has become endemic in certain species of game in certain areas in Southern Africa. Since 1931, when the disease was discovered at the Nuanetse Ranch in Southern Rhodesia, there have been recrudescences in the Victoria District in 1934, 1936, 1938 and 1943. Sufficiently long intervals, especially between 1938 and 1943, and methods of control (for instance, vaccination) ensured that the disease had died out in domestic stock. The preservation of the virus of foot and mouth disease in or on animal or vegetable products for such long intervals can be completely eliminated. (See Progress Reports: Foot and Mouth Disease Research Com-

mittee, 1925-1937). In the 1937 report of the Director of Veterinary Services, Southern Rhodesia, the following comments are significant: " In August a young Kudu cow was shot within the infected area on Devuli Ranch. The Cattle Inspector observed fresh lesions on the feet and tongue and he was fortunately able to obtain vesicle virus from one of the former. Three susceptible cattle injected reacted typically. This test furnished definite evidence that the Kudu virus was that of Foot and Mouth disease and that it was the Kudu virus of the same immunological type as that which had caused infection in cattle in the area . . . Game played a very important part in connection with recrudescences of the disease within an area many months after the disease appeared to have been finally eradicated from that area. Many of these recrudescences or fresh outbreaks have coincided with movements of cattle to fresh grazing grounds or watering places, or alternatively, with the seasonal movement of game to watering places used at other times almost exclusively by cattle. The assumption is that the disease may pass slowly through scattered herds of game, as it does under similar conditions with cattle where deliberate close contact or inoculation is not practised, with the result that months or probably a year or more might elapse before all the game in the area have become infected. The virus is thus provided with a continuous supply of suitable material (susceptible animals) in which to propagate. Then, at a favourable moment for infection to supervene, a buck in the short period of its infective stage makes contact with susceptible cattle and the disease starts again in cattle."

The outbreak of foot and mouth disease at the Colliery farm in the Wankie Area, Southern Rhodesia, in August, 1940, is also significant in view of the fact that it occurred in a herd of cattle isolated in a tsetse fly belt. There was, therefore, no possible chance of infection being brought in by domestic stock. In the adjoining Wankie Game Reserve hoof specimens were obtained from a Kudu bull and buffalo and these revealed changes highly suggestive of foot and mouth disease.

In the Bechuanaland Protectorate outbreaks (1933-1934, widespread) (1937, Palapye Road), and (1944, Ngamiland), long intervals between active disease in domestic stock are also recorded. During the 1933 outbreak, when all cattle in infected areas were vaccinated, the disease was reported in wildebeest, probably contracted from active infection in cattle.

In Northern Rhodesia similar outbreaks are recorded. (Widespread in the southern part, 1933) (Kazungula, 1934), (Mamwala District, 1934) (Sananga, Barotseland, July, 1941) (Lusaka and Mazabuka, 1942). The disease broke out again in Mamwala in March, 1944, in a herd in an area of approximately two to three square miles isolated by impassable swamps and fly belts. In this, infection spread by domestic stock played no part.

In 1937, the Portuguese authorities were adamant that foot and mouth disease had come from the eastern boundary of the

Kruger National Park via Uanetse (opposite Satara) to Moamba, from where it spread rapidly. They were of opinion that game along the frontier of the Kruger National Park was responsible for the invasion of Portuguese East Africa. From there it spread (in December, 1937) into the Komati Ward, Barberton District, i.e., across the border. In December, 1938, a large number of farms in the Pilgrims Rest area adjoining the Kruger National Park, and the Skukuza Rest Camp became infected with foot and mouth disease. In March, 1939, the Komati Ward in the vicinity of the Kruger National Park was again infected. In all these outbreaks all stock, infected and in-contacts, were slaughtered and buried and the infection in domesticated animals completely eliminated.

In December, 1944, after a lapse of more than four years foot and mouth disease again made its appearance on farms in the Komati Ward and Pilgrims Rest district. These farms adjoined the Kruger National Park. From the Pilgrims Rest district the disease was spread across the Olifants River by a movement of cattle. It was reported that before the recent rains came game were dying in the southern part of the Kruger National Park as a result of the drought. In December, reports were received of lame Impala between Pretorius Kop and the Limpopo and this condition was attributed to a deficiency disease. At that time the Crocodile River could be easily forded in places and there was every possibility for migration onto the adjoining farms and in that way contacting stock. A fair number of specimens were recovered from game showing signs of lameness, and from the appearance of the lesions on the hoofs, the only diagnosis that could be arrived at was foot and mouth disease. Several attempts were made to transmit the disease to guinea pigs with material derived from game. Unfortunately in these specimens the virus could not be isolated because the disease was too protracted and no intact vesicles were found. An in-contact experiment with cattle in the Game Reserve also gave negative results probably due to the fact that when the experiment was commenced the infection in the in-contact game had probably expended itself. (These experiments and observations will be fully commented on by Alexander, de Lange and others.) As a result of these outbreaks more than 60,000 head of cattle became infected in the Barberton, Pilgrims Rest and Letaba districts. Large areas have been placed under quarantine and the infected herds cordoned off. These outbreaks have completely disorganised farming activities in the infected areas and the Government is experiencing great difficulty in disposing of the stock in the infected area in order to prevent further spread and to eliminate the infection. In the Kruger National Park the following outbreaks are recorded:—

(a) July, 1938—At Satara amongst nine head owned by Ranger Ledeboer.

(b) September, 1938—A suspected case at Gudzana, 13 head involved.

(c) December, 1938—At Skukuza amongst eight head owned by Col. J. Stevenson-Hamilton.

In respect of the Gudzana investigation the guinea pig tests were negative but from the experience gained in the Dundee district, Natal, we must accept this as foot and mouth disease. We were not able to isolate the virus in the Gudzana cattle on account of the age of the lesions.

It may be of interest to refer to an epizootic of foot and mouth disease which occurred in wild animals in captivity in the Zoo in the Bois de Vincennes in Paris. (Ubrain, Bullier, and Nouvell of 1938.) Out of 250 susceptible animals in the Paris Zoological Gardens, 32 were infected during an outbreak and four died. The symptoms encountered in the different species are described and the varying degrees of susceptibility are discussed. Immunisation by serum-virus inoculation was carried out to a limited extent. Passive immunisation was preferred and this, combined with isolation and adequate disinfection, limited the spread of the disease and the mortality.

All the animals affected were ungulates. The infection first appeared in Bovidae, with symptoms similar to those observed in domestic cattle. A "kouprey" (*Bos sauveli*), a gaur (*Bos gaurus*) and three buffaloes (two *Bos bubalis* and one Rumanian) recovered after treatment with antiserum and *pus aseptique;* a gayal (*Bos frontalis*) succumbed to the infection; three other Rumanian buffaloes and a number of African buffaloes (*Bos caffer*) were immunised with antiserum and remained well. Two American bison (*Bos bison*) were affected. Several varieties of deer and antelope received immune serum or citrated blood from a recovered animal; only a few developed symptoms and these were of a nervous character; one deer (*Dama dama L.*) succumbed. Sheep, goats and moufflons were given serum and remained well. Animals of the Suidas family were very susceptible; the babiroussas (*Babirussa babyrussa*) were affected and, after inoculation with antiserum and virus, four wild boars contracted the infection, one *Potamochoerus porcus* had a severe reaction and two out of four wart hogs (*Phacochoerus aethiopicus*) reacted. All recovered after treatment with antiserum. Four Tapiridae contracted the disease and recovered; pigs and tapirs had lesions confined mainly to the feet. Two guibs (*Tragelaphus scriptus*) died, one after double inoculation and one untreated. Dromedaries, camels, llamas and alpacas were immunised with antiserum and remained well: giraffes and hippoptami were not immunised and were not affected."

There is therefore a strong suspicion that the disease has probably become endemic in certain species of game in certain parts of Southern Africa in the same way *as this disease remains endemic in cattle* in certain countries where the slaughter out policy is not adopted (for instance, Argentine and Kenya). Game has probably become infected in Southern Africa by the dissemination of virulent un-attenuated virus during the vaccinations

carried out in Southern Rhodesia, Northern Rhodesia and the Protectorate.

This serious outbreak of foot and mouth disease completely disorganising farming activities in a great part of Eastern Transvaal, should receive the earnest consideration of all the authorities concerned; e.g., the Central Government, those entrusted with the welfare and preservation of game, and the farming community. Every endeavour must be made to prevent a recurrence in the future and methods will have to be devised by means of which the Kruger National Park can be isolated from any possible contact with stock along its boundaries. Various types of fencing should be investigated and natural barriers explored. Cattle-free zones will have to be established. Last but not least further research should be undertaken and the question of the reservoir host should be investigated. These investigations will have to be conducted in a place or places where complete isolation can be ensured (in Germany foot and mouth disease investigations were carried out on the Island of Rheims) or in an endemic area in view of the highly infectious nature of the virus of foot and mouth disease. The closest collaboration of neighbouring states should be sought. Investigations of this nature, especially involving the part played by the "animal carrier" presents many obstacles and difficulties, which would manifest themselves to a much greater extent in game on account of their wild nature and habits.

Rinderpest in Game.

Thomas and Reid (1944) refer to reports in 1939 of game dying from rinderpest in Tanganyika, in the Kilimbero Valley on the eastern flank and in the Saka Game Reserve on the western game flank. This preceded the reappearance of the disease in cattle in the Usanga plains. In the March Reports, 1940, it was stated that rinderpest was found in buffalo south of the Kilimbero River and it was also confirmed in buffalo south of the Rufiji River. This southward spread of rinderpest in game in Eastern Tanganyika was viewed with the gravest concern, especially on account of the nature of the country and the difficulty of communications and transport (Alexander and De Kock, 1940).

There was a very real danger that rinderpest may be carried in game into Southern Tanganyika and from there overflow into Portuguese East Africa. This aspect was the subject of the closest observations, and measures were considered to counteract this spread of the disease in game by establishing effective cordons at most suitable points and creating game-free belts. (Blantyre Conference, 1940.) In 1940, all the cattle in Tanganyika below the central railway were immunised, and rinderpest was eliminated in cattle by these highly successful methods of prevention (Mitchell and others, in the press).

Apparently rinderpest continued to smoulder in game. with a serious recrudescence in June, 1941, north of the Tanganyika-Northern Rhodesian border. There was a serious threat of the

disease spreading in game across the border. Some authorities were of opinion that infection in game (e.g., Eland Buffalo, etc.) may be carried a considerable distance in a comparatively short time. In view of their migratory habits, it becomes far more difficult to control the spread of rinderpest by game than by cattle. The timely action taken by the Tanganyika authorities saved the situation.

By means of a game fence erected early in July, 1941, and stretching across the Saise Valley, a distance of 26 miles, the spread of rinderpest in game towards the south was averted. In order to ensure the position a second bush fence and a cordon of pickets along the inter-territorial border were provided. (Mebya Conference, 1941.) This was further strengthened by the creation of a game-free belt on the border. During this campaign a great deal of information was acquired in respect of the disease in game and the value of different game fences. By means of annual immunisation of all susceptible cattle north and south of the border between Northern Rhodesia, Nyasaland and Tanganyika extending to the central railway (from Dar es Salaam to Tabora), rinderpest completely disappeared in that area. In 1944, the position was reported to be so favourable that the routine immunisation of yearling stock in the area referred to above, was discontinued. Unfortunately early this year the position of rinderpest in game north of the above railway line appeared to have deteriorated very materially, so much so that a conference of all States concerned will take place early in August to review the whole rinderpest position in Tanganyika and to explore methods by means of which these threats of the disease in game to the States to the south can be permanently averted.

De Kock and others (1938) dealt with various aspects of the swine fever problem in South Africa. From the observations made and the investigations carried out, it seems more than likely that the source of the outbreaks since 1928 must be attributed to infection in the wild pig. From a preliminary survey it would appear that certain areas in the Northern Transvaal harbour warthogs, amongst which a small percentage are carriers of the virus of swine fever. In warthogs no symptoms of or deaths from swine fever have been recorded, although blood collected from some of them has set up swine fever in a very virulent form in domestic pigs experimentally. A survey of this problem is long overdue. Lack of information re the extent of spread of infection in the carrier host, leaves no alternative but the maintenance of irksome quarantine measures in order to prevent a recurrence of the widespread infection of 1934-35.

The extent to which the Viverridae are responsible for the transmission of rabies to man, domesticated and wild animals has been commented on by Snyman (1940). The part played by the Cynictis species in perpetuating the virus among themselves was referred to as well as their distribution habits, and the difficulties attending the control and destruction of these wild

carnivores in South Africa. Various methods of destroying the Cynictis species in infected areas have been investigated, and a stage has been reached indicating how the carrier host can be eliminated if suitable facilities are provided.

Brief reference should be made to the part played by the wildebeest in sporadic outbreaks of malignant catarrh (snotsiekte) of cattle in certain areas in Southern Africa. From time to time outbreaks of this disease in cattle are recorded and in some instances it would appear that the virus in certain localities has been transmitted to certain classes of sheep. In sheep no mortality attributed to snotsiekte has been recorded, although they may harbour the virus, apparently for considerable periods and cause mortality in susceptible cattle by contact. (De Kock and Neitz, paper to be published).

Amongst the bacterial diseases mention should be made of the problem of tuberculosis especially in Kudu, in the Albany and adjoining districts of the Cape Province. The disease was originally most likely transmitted to Kudu by infected cattle. In the Kudu it has now unfortunately become endemic, so much so that it has become a stock-farming problem of the first magnitude in the infected area.

The part played by game as a carrier host in sleeping sickness and nagana has been frequently discussed, and at the Pan-African Agricultural and Veterinary Conference in 1929, the following resolutions were adopted:—

(4) Scientific evidence is now sufficient to justify the following conclusions:—

(a) Game constitute the most important reservoir of the trypanasomes, pathogenic to domestic animals;

(b) game constitute the most important source of food to the open forest tsetse flies such as G. Morsitans and G. Pallidipes.

(5) To ensure the perpetuity of Game Reserves and to prevent their constituting a menace to surrounding districts, they should be free from Glossinae.

A campaign is being undertaken in Zululand to eliminate the tsetse fly by the destruction of game in certain areas as well as by trapping operations, and judicious bush clearing (breeding sites) and fires, every precaution being taken to prevent soil erosion. Investigations are being continued to ascertain the incidence of infection in the carrier hosts, as well as a study of the fly in relation to its environment, the Harris trap, etc., and the value of certain insecticides and how best these can be applied on a large scale to destroy the fly.

Apart from these problems where game plays a significant role in perpetuating and spreading certain diseases, factors of drought and starvation need careful consideration. Sufficient grazing should be made available in Game Reserves, implemented by judicious veld management and by preventing overstocking. The problem of soil erosion and the destruction of the

national flora in Game Reserves by fires, etc., should receive very careful consideration.

From the above remarks it becomes sufficiently clear that there are serious major problems confronting game conservation in Southern Africa. It necessitates the application of the knowledge so far accumulated by observation and research, and the creation of the necessary machinery to investigate those problems about which more information is sought.

An appeal is made to the Central Government to take a lead and convene a meeting of all interests concerned to consider how best the existing procedure of conservation can be improved and consolidated by a systematic, and comprehensive plan of national scope to secure perpetuity of Nature Reserves. The Government should take personal responsibility for the conservation of native wild life under a central State Authority with expert personnel.

REFERENCES.

ALEXANDER, R. and DE KOCK, G.: "Rinderpest in Southern Africa." *Farming in South Africa* (May, 1940).

BIGALKE, R.: "The Naturalisation of animals with special reference to South Africa." *This Journal.* **XXXIII:** 46-63 (1943).

DE KOCK, G.: "Wild Animals as Carriers of Infection." *S.A. Med. Journal.* 1-15 (October, 1938).

DE KOCK, G. and others: "Swine Fever in South Africa." *Onderstepoort Journal.* **14:** Nos. 1 and 2 (1938).

DE KOCK, G. and NEITZ, W. O.: "Reservoir host in Snotsiekte." (To be published).

HUDSON, E. H.: "The Role of the Reservoir Host in Tropical Disease." *The Am. Journal of Trop. Med.* **24:** No. 2 (March, 1944).

MITCHELL, D. T. and PEEVIE, W. G. G.: "The manufacture of Anti-Rinderpest spleen vaccine under field conditions in Tanganyika Territory." *Onderstepoort Journal* (in Press).

PAINE, R. and MARTINAGLIA, G.: "Tuberculosis in Wild Buck living under Wild conditions." *Journal Comp. Therap.* **XLII:** No. 1,, 1-8.

STEVENSON-HAMILTON, J.: "South African Eden." Cassell & Co., London (1937).

SNYMAN, P.: "The Study and Control of the Vectors of Rabies in South Africa." *Onderstepoort Journal.* **15:** Nos. 1 and 2.

THOMAS, A. D.: An official communication (1945). "The Dassie (*Procavia capensis*) as a pest in the Karoo."

THOMAS, A. D. and NEITZ, W. O.: "The importance of Diseases in Wild Animals." *This Journal.* **XXX:** 419-425 (1933).

THOMAS, A. D. and REED, N. R.: "Rinderpest in Game." *Onderstepoort Journal of Vet. Science.* **20:** No. 1 (September, 1944).

UBRAIN, A., BULLIER, P. and NOUVELL, J. (1938): "An outbreak of Foot and Mouth disease in Wild Animals in Captivity." *Bull. ACAD. Vet.* Fr. II. 59-73 (Extract in *Vet. Bull.* 22 (Jan., 1940).

Report of the Rinderpest Conference, Mebya, 1939.

Report of the Rinderpest Conference, Mebya, 1941.

Report of the Rinderpest Conference, Blantyre, 1940.

Reports of the Pan-African Agriculture and Veterinary Conference, Pretoria, 1929.

Report of Chief Veterinary Surgeon, Southern Rhodesia, 1937.

Progress Reports of Foot and Mouth Disease Research Committees. Ministry of Agriculture and Forestry. Five Reports, 1925-1937.

Report of the Committee on Nature Conservation and Nature Reservation. *The Journal of Animal Ecology* Vol. XIII No. 1—May, 1944 (This report was freely quoted).

South African Journal of Science, *Vol. XLII, pp. 172-173, June, 1946.*

BREEDING SEASONS FOR GAME BIRDS

BY

Dr. Austin Roberts.

Read, 2nd July, 1945.

Abstract.

This paper was compiled at the request of the Wild Life Protection Society of South Africa to furnish evidence for submission to the Transvaal Game Laws Enquiry Commission.

The subject in so far as wild ducks are concerned had been discussed in a Johannesburg newspaper and in the Journal of the South African Ornithological Union in 1907; but although there was a little evidence of some ducks being known to breed in the winter (April to August), during the " open " shooting season, nothing was done about it. The other Game Birds were not considered at that time. In those days the Korhaans or Bustards (*Otidae*) were considered Game Birds, but were later removed as specially protected birds for their usefulness in the destruction of harmful insects, such as locusts and termites. Quail and Snipe, though " sportsmen's birds " and the edible doves and pigeons have never been placed on the list of Game Birds, which now embraces only the ducks (*Anatidae*), Guineafowls (*Numididae*), Francolins or Partridges (*Phasianidae*) and Sandgrouse species (*Pteroclidae*).

There are fewer sportsmen today than three decades ago, in proportion to the greater European population in South Africa, and more people in favour of protection of birds than formerly; but some people still keep up the old tradition of sportsmen, and they are asked to note the fact that some of our Game Birds breed during the " open " shooting season and they are asked not to shoot the game birds found singly or in pairs, as such occurrences are a sure sign that the birds have nests or young or have paired off.

The difficulty of fixing a definite shooting season is that all the four species of Sandgrouse, six of the sixteen species of Ducks and one of the eleven species of Francolins and Partridges are known to breed normally during the shooting season allowed by law; and sometimes other species that normally breed in the summer or "closed " season, also breed in the "open " season. The Guineafowls always breed during the summer months, as

also most of the Phasianids and ducks. What should be done about the protection of those that breed in the "open" shooting season is left to the sportsmen to decide.

Evidence was procured from records of eggs of Game Birds in the Transvaal and Durban Museum collections, from ornithological journals and books, of eggs and young birds observed by various amateur ornithologists and from the author's own observations in the field. Summed up these are as follows:—

Duck Family (*Anatidae*).

	Records for Summer Breeding.	Records for Winter Breeding.
Spurwing Goose	(Numerous)	1
Egyptian Goose	4	5
South African Shelduck	2	6
Knobbilled Duck	4	2
Dwarf Goose	4	—
Cape Shoveller	3	—
South African Black Duck	—	13
Yellowbill Duck	12	9
Redbill Teal	11	3
Cape Wigeon	1	5
Hottentot Teal	—	2
Whitefaced Duck	8	—
Whistling Duck	2	4
South African Pochard	14	1
Maccoa Duck	1	—
Whitebacked Duck	6	5

Francolins and Partridges (*Phasianidae*).

	Records for Summer Breeding.	Records for Winter Breeding.
Swempie or Coqui Partridge	6	1
Bush Partridge	8	—
Greywing Partridge	6	2
Shelley's Partridge	6	1
Redwing Partridge	4	2
Orange River Partridge	5	—
Cape Francolin	3	—
Redbill Francolin	2	2
Rednecked Francolin	3	—
Swainson's Francolin	6	2
Natal Francolin	—	9

All records for the Sandgrouse show winter breeding, and all records for Guineafowls show only summer breeding.

A POSSIBLE EXPLANATION OF THE DENTITION OF *HYDROCYON LINEATUS* AND ALLIED FISHES.

BY

DR. F. GORDON CAWSTON.

Read 2nd July, 1945.

ABSTRACT.

Examination of the teeth of the Tiger Fish from the Sabi River before the gum has hardened reveals free movement of the row of buried teeth facing the fullet which had been thought to exist merely for replacing teeth lost from the upright row.

These backwardly directed teeth develop to practically the same size as those of the erect row and they would not appear to alter their position through the life of the fish for there is no trace of other tooth-formation than that of the two rows. The inference is that these buried teeth serve to steady the gum as they lie beneath it.

CHANGING FOOD HABITS

BY

DR. T. W. B. OSBORNE.

Read 3rd July, 1945.

South African Journal of Science, *Vol. XLII, pp. 175-204, June, 1946.*

THE CRANIAL ANATOMY AND KINESIS OF THE SOUTH AFRICAN AMPHISBAENID *MONOPELTIS CAPENSIS* SMITH.

BY

C. C. Kritzinger.

Zoological Institute, University of Stellenbosch.

Read 2nd July, 1945.

Introduction.

The family *Amphisbaenidae* (Gray, 1825) represents an interesting group of snake-like burrowing lizards; practically all herpetological works refer to the peculiar adaptations of these lizards. Extensive anatomical research on the family is, however, restricted to von Bedriaga's work (1884) on *Amphisbaena cinerea* Vand. and *A. Strauchi* v. Bedr. It was not found possible to consult some of the older literature, such as that of Smalian (1885) frequently referred to by later workers. Cope (1892) in his comprehensive osteological work also discussed the Amphisbaenidae, and gave a brief survey of the cranial anatomy of *Rhineura floridana*. Versluijs (1898, 1912) gave a detailed description of the middle ear and related structures of *Amphisbaena* and *Trogonophis*, and of the kinesis in the skull of the family in general. Lakjer (1927) investigated the palate of three genera: *Amphisbaena*, *Trogonophis* and *Lepidosternon*. Despite the above, anatomical research on the Amphisbaenidae has on the whole not been plentiful, and the present paper is an attempt to supplement our somewhat scanty knowledge of the anatomy of these highly specialised lizards.

For historical details of the taxonomic and phylogenetic position of the Amphisbaenidae the reader is referred to von Bedriaga's work (op. cit.). The genus *Monopeltis* was instituted by Smith (1848) for the species *M. capensis* Smith. Gray (1865) gave the name *Monotrophis* to this genus, but Peters (1867) reinstituted *Monopeltis* and this name has since been adopted permanently. Boulenger (1910) gave six species for the genus; in the latest taxonomic work, that of Loveridge (1941), seventeen species are enumerated and the author changes *M. capensis* Smith to *M. capensis capensis* Smith.

The Present Investigation.

1. Material and Technique.—Microtomised sections (20μ) were made of two specimens of *M. c. capensis* Smith. They were collected in the Nylstroom district, Transvaal and

were fixed in formol by Mr. N. J. van der Merwe of this Zoological Institute. After removal of the head shields and the skin around the neck, the heads were severed and the objects then decalcified in Ebner's fluid for twenty days. Prolonged decalcification was thought advisable on account of the notorious difficulty experienced in decalcifying reptilian bone. In toto staining with haemalum and counter staining with von Gieson's solution yielded excellent results. Graphic reconstructions were made with the aid of the Panphot-projection apparatus and a micrometer scale.

2. Nasal Region.—Owing to the burrowing habits of *Monopeltis*, the nasal region of its skull shows marked specialisation as indicated by extensive thickening of the membrane bones of this region and by a marked reduction of the cartilaginous capsule; this latter feature is remarkable when the chondrocranium of *Monopeltis* is compared with Gaupp's figures (1900) and Ziegler's model of the skull of *Lacerta agilis*. (See Figs. 1 and 2.)

The taeniae and cartilaginous planum supraseptale are entirely absent, and the septum nasi bifurcates into two short trabeculae immediately behind the nasal capsule, thus rendering the skull platytrabic according to de Beer's nomenclature (1937). (Cp. the Ophidia). According to von Bedriaga (op. cit.) and Versluijs (1924) the skull of the genus *Amphisbaena* is also platytrabic. This condition differs from that in other Lacertilia: the platytrabic condition of the Amphisbaenidae being undoubtedly due to specialisation associated with burrowing habits. Such specialisation gives the skull the necessary firmness, effected by the anterior prolongation of the ossa prootica against which the nasal region finds support.

The Cartilaginous Nasal Capsule (Fig. 3).—Is represented by a number of cartilagious bars supporting the more completely retained side walls in which the concha nasalis, lodging the glandula nasalis lateralis, is situated. The duct of this gland is fairly long, passes forwards along the side of the cartilaginous capsule and, after turning medially above the maxillary, opens medioventrally into the nasal cavity. In this respect *Monopeltis* differs from most Lacertilia in which the duct, when present, is short and opens dorso-laterally. On each side of the capsule a number of large fenestrae are formed, representing the fenestra superior, fenestra lateralis and foramen epiphaniale, this last situated immediately dorsal to the aditus conchae and allowing passage for the ramus lateralis nasi on its way to the glandula nasalis lateralis and the skin. The foramen apicale is enlarged and antero-dorsally situated; the ramus medialis nasi and a small artery emerge directly from the septomaxillary (see below) through the for. apicale on to the dorso-lateral side of the capsule. Owing to the small size of the tectum nasi the fenestra olfactoria evehens is very large, being bounded posteriorly by the commissura sphenethmoidalis. A small vestige of the paraseptal car-

tilage is present. The processûs maxillares posteriores and anteriores are represented by vestiges of cartilage. (See Fig. 3.)

The cupolae anteriores project for a considerable distance anterior to the septum nasi, and only the processûs alaris inferior is represented and forms the postero-medial boundary for the fenestra narina (Fig. 4). Small foramina in the tips of the cupolae are probably the result of progressive capsular reduction. Similar foramina are formed in the side walls of the capsule: the one specimen has one and the other two such foramina. (See Fig. 4.)

The ventral portion of the vestiges of the zona annularis is not in synchondrotic continuity with the rest of the capsule. It bears a slender cartilago ectochoanalis and an anterior vestige of the paraseptal cartilage (Fig. 5). The lamina transversalis anterior forms the basal support for the organ of Jacobson, and the cart. ectochoanalis projects backwards between the vomer and the maxillary. Lamina transversalis anterior and cart. ectochoanalis are the only constituents visible ventrally; the Lacertilian solum has undergone great reduction as in birds.

The skeletal capsule of the Lacertilian *organ of Jacobson* is partly cartilaginous and partly bony. (Cp. Broman, 1919). In *Monopeltis* (Fig. 5) the septomaxillary constitutes the anterior, dorso-lateral and part of the medial walls of the capsule; ventrally the organ rests upon the lamina transversalis anterior of which the centrally situated " pilzförmiger Wulst " of Gaupp (1900) is a derivative. Posteriorly the vomer forms the floor and hind wall of the capsule. The medial wall is formed by the septomaxillary, the septum nasi and the vomer. (See Fig. 5.)

The duct connecting the lumen of the organ with the oral cavity is very small, so that a considerable amount of pressure would have to be exerted before the contents of the lumen will be discharged into the mouth. This is brought about by the following mechanism: when the anterior region of the skull is kinetically lifted, the vomers press against the lamina transversalis anterior; the " the pilzförmiger Wulst " of the latter is displaced towards the lumen of the organ, thus discharging its contents into the oral cavity. When pressure is released, fluid from the oral cavity and from the nasolacrimal duct is sucked into the lumen. (Cp. Broman, op. cit.). This explanation finds support in the fact that the connective tissue between the vomer and the lamina transversalis anterior is reduced to a minimum. Moreover, the presence of a symmetrical lymph space between the septum nasi and the vomers indicates the possibility of a certain amount of movement of the latter (Fig. 5). The presence of a continuous plate-like layer of epithelium unaccompanied by vomerine glands, renders any pressure exerted upon the oral roof more efficient in effecting the discharge of the contents of the organ of Jacobson.

The Membrane Bones Associated with the Nasal Region.—These bones present a solid entity, the constituting elements being rigidly joined together by means of interlocking processes and squamae, and dense connective tissue cementing the different bones together. Since the cartilaginous capsule is in the process of degeneration, the bony capsule functionally substitutes for the former in forming a protective casing for the nasal cavities, nerves and bloodvessels.

The fused premaxillaries show a tendency towards extensive thickening, probably correlated with the burrowing habits of the animal. Owing to its considerable height, the premaxillary for some distance prevents the cupolae anteriores from fusing (Fig. 4). Immediately anterior to the septum nasi the premaxillary splits into three processes (Figs. 1 and 2): (a) an upper processûs frontalis (von Bedriaga, op. cit.) projecting backwards to the middle of the frontals, thus covering the septum, and (b) and (c) two lower palatal squames (processûs palatini ossis intermaxillaris von Bedriaga, op. cit.), each of which possesses a ventral extension to the maxillary of its side, thus forming a partial secondary palate of the Mammalian-Crocodilian type (not sensû Fuchs, 1908).

Each *maxillary* can be divided into approximately three portions: (i) a well-developed processûs palatinus ossis maxillaris produced rostrad above the corresponding process of the premaxillary, and even reaching beyond the septomaxillary; medially the process extends to the vomer from which it is separated by the choanal groove and the cart. ectochoanalis, (ii) a vertical squame, the dorsal process, forming a bony side wall to the cartilaginous capsule and partly overlying the frontal and the nasal, (iii) a long slender posterior process against which the vestigial transversum is closely applied ventrally. Anteriorly this process forms a dorsal groove in which the pterygoid rests, but posteriorly the process itself lies in a ventral pterygoidal groove (Text-fig. 2). The anterior portion of the lacrimal is wedged in between this posterior process and the dorsal process referred to above.

The Dentition of the Upper Jaw.—The teeth of the lower jaw will be discussed later. In the upper jaw only the fused premaxillaries and the maxillaries bear teeth: the former four and the latter three each. Loveridge (op. cit. gives the premaxillary dentition as a single median tooth, but the sections reveal two teeth, one being situated medially and a little more to the front than the other which is located on the right side. Except these two, another pair of very minute teeth are found posteriorly on the palatine processes of the premaxillary. According to Parker (1936) the maxillary dentition is 2—2, but I can confirm Loveridge's statement (op. cit.) that it is 3—3, the last tooth being only 80μ in width. It would thus seem that Loveridge was correct when he concluded that " the dentition of a given species may be subject to some variation so that it is not quite so diag-

nostic of a species as was originally supposed." (Op. cit., p. 355). As might be expected in a specialised, degenerate family like the Amphisbaenidae the teeth are not readily referable to the acrodont or pleurodont types, although pleurodonty is apparently more typically represented in the lower than in the upper jaw, in which the teeth tend to shift on to that portion of the bones of the secondary upper jaw constituting the secondary palate.

The Septomaxillary.—Is intimately connected with the organ of Jacobson which is encapsuled anteriorly by the septomaxillary alone, whereas posteriorly only the roof is formed by this bone, and the floor of the organ at this level is formed by the lamina transversalis anterior and the vomer. In this region the septomaxillary consists of a short median dorso-ventral process contiguous with the septum nasi, and of an oblique flange covering the organ dorso-laterally. The septomaxillary rests upon the palatine process of the maxillary. The connective tissue between the septum nasi and the septomaxillary almost completely disappears; this is probably due to pressure exerted upon the skeletal capsule of the organ of Jacobson when the latter is being filled. (Cp. Malan, 1940). The ramus medialis nasi accompanied by a small artery passes through a foramen in the anterior tip of the septomaxillary.

The Vomers.—Concerning the homologies of these palatal elements a considerable amount of work has appeared, and Broom (1935) proposed that these elements should be called prevomers. Recently, however, Parington and Westcoll (1940) denied the validity of Broom's nomenclature, and it would perhaps be better to retain the old terminology until the homology of the vomer shall have been finally elucidated.

In his work on *Amphisbaena*, von Bedriaga (op. cit.) states that the vomers are intimately fused with the palatines, forming a " Vomeropalatinbein " on either side. Lakjer (1927) working on *A. alba*, *A. fuliginosa* and *A. vermicularis* (p. 159) says: " Die Vomera sind untereinander, nur nicht ganz hinten wo sie ein wenig divergieren, suturverbunden. . . . . . Die schmale gemeinsame Vorderspitze ist vorn mit der Premaxille, lateral mit dem Medialfortsatz der Maxille suturverbunden; caudal davon findet sich die tiefe incisura Jacobsoni." It should be pointed out that Lakjer also states that the vomers are movable against the maxillaries; one of these statements must be erroneous and I am inclined to think that it is the former. De Villiers (1939) has shown that in *Acontias meleagris*, another burrowing form of the Scincomorpha (Camp, 1923), the vomers are fused anteriorly only (cp. Lakjer for *Amphisbaena*), the fused tips projecting forwards above the premaxillaries.

The condition in *Monopeltis* differs from that obtaining in other genera mentioned above, inasmuch as the vomers are neither fused with each other nor with neighbouring elements. They project forwards above the premaxillary, thus entering

Fuchs's (1908) " primitiver Gaumen " which, according to that author, is that part of the palate formed by the premaxillary and lying anterior to the orifices of the organ of Jacobson. Behind these orifices each vomer spreads laterally towards the maxillary from which it is separated by the cart. ectochoanalis in front and the choanal groove behind; there is no indication of sutural connection between the vomer and the maxillary. Posteriorly the vomer has a process stretching backwards for a considerable distance, ventral to the palatine and immediately lateral to the processûs cultriformis of the parasphenoid, but only the most caudal tip lies ventral to the parasphenoid. The lateral squame of the vomer is trough-shaped, the groove facing downwards as in *Acontias* (de Villiers, op. cit.) and not upwards as in most Lacertilia (cp. Malan, op. cit., for *Gerrhosaurus*). The trough is lined by the epithelium of the choanal groove, extending backwards in a similar palatine excavation. The relation of the vomer to the organ of Jacobson has already been discussed.

The Nasals.—As will appear from Fig. 1, the nasals extend forwards approximately in line with the premaxillary. The tip of the skull therefore assumes a rounded, dorso-ventrally flattened form, well adapted to the burrowing mode of life of the animal. The nasals are separated by the processûs frontalis of the premaxillary which is also slightly prolonged over them. Laterally and posteriorly the nasals underlie the maxillaries and the frontals, unlike the condition in most Lacertilia where the relation is reversed. The fenestra superior of the cartilaginous nasal capsule is completely covered by the nasal of its side. (See Fig. 6.)

The Frontals.—Do not belong to the nasal region, but in *Monopeltis* the parietal is enlarged at the expense of the frontals to such an extent, that the latter belong topographically to the nasal rather than to the orbito-temporal region. This seems to be the case in all genera of the Amphisbaenidae (cp. von Bedriaga, op. cit., and Lakjer, op. cit.). It will be seen from Text-fig. 4 that the anterior tips of the frontals are wedged in between the premaxillary medio-dorsally and the nasals ventro-laterally. Since the frontals curve over to the dorsal processes of the maxillaries, the nasals are completely covered posteriorly. The prefrontal is lacking, and the glandula nasalis lateralis is covered by the lateral squame of the frontal, overlying the greater part of the lacrimal.

The frontals have interesting relations to the anterior prolongation of the cavum cranii (Fig. 6a and 7); immediately behind the processûs frontalis of the premaxillary the anterior portions of the downgrowths of the frontals bound the cavum cranii. Each of these lamellae arises obliquely from the ventro-lateral flange and curves towards the median line where it approaches its fellow of the other side above the septum. The cavum cranii is thus produced rostrad, and the olfactory lobes and the cerebrum are

encapsuled by the frontals only. Anterior to the paired trabeculae the parasphenoid is dorso-ventrally forked; the larger dorsal splint is T-shaped, the lateral wings of the T being very loosely clamped by the lamellae (Fig. 7). It is interesting to note that these frontal lamellae actually effect contiguity with the palatines (Text-fig. 6a.). Brock (1941, p. 81) states for *Amphisbaena:* " The downgrowths of parietals and frontals have formed a solid cranial box extending to the skull floor and entirely obliterating the interorbital septum." (See Fig. 7.)

A comparison of serial sections of *Monopeltis* and of the Colubrid snake *Homalosoma lutrix* reveals a striking similarity. Fig 6b represents a section of *Homalosoma* behind the short trabecula communis. As in *Monopeltis*, the parasphenoid is anteriorly forked, lying dorsal and ventral to the septum. The downgrowths slant obliquely in a dorso-ventral direction and approach each other *above* the parasphenoid; they are linked to each other and to the parasphenoid by means of dense connective tissue. The cavum cranii thus enclosed is triangular in transverse section and not oval as in *Monopeltis*, since the absence of eyes in the latter form apparently allows for additional expansion of the cavum cranii. In *Acontias meleagris* the frontals likewise form a cranial box which is oval in transverse section, but tends to be triangular as in *Homalosoma*. This condition appears to be a confirmation of the theory that the Scincidae are closely related to the Ophidian stock.

The Orbito-Temporal Region.—The burrowing mode of life of *Monopeltis* has considerably affected the orbito-temporal region. In most Lacertilians the nasal and otico-occipital regions are linked by means of bony arches, cartilaginous taeniae and a long inter-orbital septum. In *Monopeltis*, however, the otico-occipital region projects forwards to within reach of the nasal region, thus providing a firm support for the latter. Such support is acquired at the expense of the frontals and the interorbital septum, these elements being very short. (Cp. Versluijs, 1912). Cartilaginous taeniae are not represented and the postorbital and temporal arches have apparently disappeared. Since the cranium in the orbito-temporal region is wide, the skull assumes a smooth, rounded appearance well adapted to fossorial habits (cp. Peter, 1898); consequently the orbit is a very small space wedged into the maxillo-frontal angle; ventrally it is bounded by the pterygoid and the palatine, and laterally by connective tissue only (Fig. 7.). The postfrontal is absent. The orbit is almost entirely filled by the large Harderian gland. The eye is represented by a vestigial nodule, 300μ in length and 100μ in width.

Presumably as a specialisation resulting from the burrowing habits, an additional bony element exists immediately behind the nasal region, thus helping to form the necessary support for this region. Von Bedriaga (op. cit.) has drawn attention to the existence of orbitosphenoids in *Amphisbaena*. He states (op. cit., p. 53): " Als Orbitosphenoidea bin ich geneigt andere, an die

eben beschriebenen Frontalfortsatze angrenzende Knochenplättchen zu betrachten und zwar diejenigen, welche beim Auseinanderlegen des Amphisbaena-Schadels stets am Para- und zum Theil auch am Basi-Sphenoideum angeheftet bleiben.'' Lakjer (1927) describes a sutural connection of the parasphenoid and the orbitosphenoids for *Amphisbaena* and *Lepidosternon*. In *Monopeltis* the orbitosphenoids are anteriorly fused above the septum, the fused tip lying well within the nasal capsule and forming in this region the floor of the elongated brain-case. (Cp. Fig. 57 in Lakjer's work, 1927.) Behind the cartilaginous nasal capsule the orbitosphenoids diverge laterally, the side wings being slightly curved and clasped between the frontal lamellae (Fig. 6a and 7). The wings project backwards medial to the prootic extension (vide Brock, 1941) and lateral to the basisphenoid, thus completing the ventral extensions of the parietal (cf. Versluijs, 1936). The foramen for the trigenminal nerve lies behind the orbitosphenoid, but is actually flanged laterally by two short orbitosphenoidal processes.

According to de Beer (op. cit.) the orbitosphenoid in *Lacerta* ossifies in the pila metoptica. Versluijs (1912, p. 633) states: "Wahrend bei den eigentlichen Eidechsen diese Wand steil bis zum Schadeldache emporsteigt, ist sie bei *Amphisbaena* so stark nach vorn ubergeneigt, dass sie horizontal liegt und so einen Boden fur den vordern Teil der Hirnkapsel bildet, der vorn bis in die Nahe der Nasenkapsel reicht." In *Monopeltis* the large size of the cavum cranii has effected a ventral displacement of the septum and of the orbitosphenoids. Judging from their position and relation to neighbouring elements, the orbitosphenoids have probably ossified in the pila metoptica as well as in the planum supraseptale. They are separated from the septum by means of connective tissue, but in some places even such dividing tissue seems to be absent or at least reduced to a minimum. There is, however, no synostotic continuity with either the parasphenoid or the basisphenoid, such as was found by von Bedriaga (op. cit.) and Lakjer (1927) for *Amphisbaena*. An investigation into the ontogeny of the orbitosphenoids would be necessary for the elucidation of the true relations of the orbitosphenoids to the primordial cartilaginous cranium.

There is only one foramen present in the orbitosphenoid, and it is situated in the region behind the anterior tip of the prootic extension. Through this foramen passes the vestige of the optic nerve. There is, however, no optic chiasma present. The eye muscles and their nerves are absent.

The Epipterygoids are absent, evidently as a result of special adaptional kinesis (cp. Versluijs, op. cit., von Bedriaga, op. cit., and Bütschli, 1910).

As stated above the postorbital arch is not represented, owing to the absence of the jugal and postfrontal. (Cp. Stannius, 1856.). Lakjer (1927) maintains that the jugal and prefrontal are

represented in *Amphisbaena*, but von Bedriaga (op. cit.) could identify a *lacrimal* only. A comparison of the figures given by these two authors, leads one to infer that the prefrontal of Lakjer is the same element as the lacrimal of von Bedriaga. Lakjer does not mention the ductus nasolacrimalis, and von Bedriaga states that he could not ascertain the presence of the "Ductus lacrimalis." Camp (op. cit.) denies the presence of a lacrimal in the family Amphisbaenidae. In *Monopeltis* the lacrimal is, however, undoubtedly present. Its anterior portion is completely covered laterally by the dorsal process of the maxillary, and dorsally by by the frontal; posteriorly it emerges on the surface through the gap between the dorsal and posterior processes of the maxillary, thus assisting in the formation of the orbital roof. At this level it has a smaller inner and a larger outer process (Fig. 2), the outer reaching backwards to the parietal (Fig. 7). Each ductus nasolacrimalis has a double orbital termination; as in *Acontias* (de Villiers, op. cit.) the main duct is closely associated with the lacrimal bone, accompanied by which it pierces the maxillary. The duct therefore possesses a bony capsule constituted by the lacrimal medially and the maxillary laterally. The relation of the duct to the choanal grooves and the orifices of the organ of Jacobson is typically Lacertilian. (Cp. Fuchs, 1908 and Broman, 1919.) Although the ductus nasolacrimalis does not lie exclusively within the lacrimal, its close association with the bone identified as such leaves no doubt that *Monopeltis* possesses a lacrimal and not a prefrontal, which latter represents topographically the anterior dermal wall of the orbit, and is to be looked upon as a circumorbital bone incorporated in the facial skeleton.

The Palate and the Skull Base.—The reconstruction (ventral aspect) of the skull of *Monopeltis* as represented by Fig. 2, will show that extraordinary transformations must have taken place in the palate and the skull base. The latter is very long and broad, gradually tapering anteriorly to the processûs cultriformis or parasphenoidal rostrum, which is dorso-ventrally forked, the lower smaller splint lying ventral to the interorbital septum to within reach of the cartilaginous nasal capsule, and the larger dorsal splint overlying the septum and extending for some distance into the nasal capsule (Fig. 6a). No trace of a margin between the para- and the basisphenoid could be found, but the region of fusion is probably at the level at which sutural cartilage appears between the skull base and the prootic bones. The parabasal canal in Lacertilia is formed between the parasphenoid and the basisphenoid; in *Monopeltis* this canal is situated in the region where the sutural cartilage, referred to above, is found, which leads one to infer that the parasphenoid extends far backwards.

The trabeculae diverge posteriorly, lying lateral to the rostrum for some distance and then fusing and co-ossifying with the skull base. Behind this fusion the skull base spreads laterally dorsal to the pterygoids. The trabeculae have been displaced forwards by the otico-occipital region to such an extent that they

seem to fuse with the parasphenoid and not with the basisphenoid, unless the latter has also been prolonged forwards. In *Lacerta*, according to de Beer (op. cit.) " the basisphenoid ossifies in the crista sellaris and in the adjacent trabeculae and basitrabecular processes." Since, however, the parabasal canal in *Monopeltis* is formed far behind the fusion of the trabeculae with the skull base, the parasphenoid must extend far backwards, and it is possible that the point of fusion lies between the trabeculae and the parasphenoid and not between the former and the basisphenoid.

The completely fused *basisphenoid* and *basioccipital* form a broad platform for the brain, and are separated from the prootic bones and the exoccipitals by means of two tracts of sutural cartillage respectively which extend backwards to the occipital condyle, and are continuous with the meniscal cartilage of the latter (Figs. 1 and 2). A deep groove divides the condyle into two portions fitting into troughs in the atlas. (Cp. von Bedriaga, op. cit.). At the level of the stapes the sutural cartilage widens considerably and forms a broad cushion on the ventro-lateral ridge of the basisphenoid (Fig. 8). This ridge is continued forwards and simulates a basispterygoid process. Versluijs (1912), Lakjer (1927) and von Bedriaga (op. cit.) have shown that the basipterygoid processes are absent in *Amphisbaena*. According to Lakjer (1927) they are present in *Trogonophis* and *Lepidosternon*. Concerning these processes in *Amphisbaena*, Lakjer (1927, p. 159) states: " Dass der Flügel, (=ridge) der hinten mit der Epiphyse suturverbunden ist, tatsächlich den Fortsatz vertritt, wird aus einem Vergleich mit den später zu erwähnenden Gattungen hervorgehen." He maintains that the ridge in *Amphisbaena* approaches but does not reach the pterygoid. In *Monopeltis* there is a synovial joint between the cartilaginous cushion and the meniscal cartilage on the pterygoid, thus indicating the possibility of movement between these elements; such a condition is, according to Versluijs (1912), essential to cranial kinesis. Judging by my own reconstruction of the skull base of *Monopeltis* and by Lakjer's (1927) figure (54) for *Amphisbaena*, the ridge in these two genera would appear to be essentially similar. The basisphenoid is very broad behind the articulation with the pterygoid, and it is probable that the ridge does not supersede the basipterygoid process as is maintained by Lakjer, but that the process participates in the formation of the anterior portion of the ridge.

The internal carotid artery runs forwards to the basisphenoid and the stapes, and then enters the short parabasal canal at the level of the anterior tip of the stapes. Here it is joined by the palatine nerve, together with which it emerges from the canal in front of the articulation between the pterygoid and the ridge. The artery then gives off a small branch which passes through a foramen in the skull base into the cavum cranii to supply the brain and the hyophysis. The main branch of the artery and the palatine nerve run forwards between the pterygoid and the skull

base. The palatine nerve branches off from the facial nerve before the latter traverses the prootic, and enters the parabasal canal through a foramen in the prootic. A branch of the palatine nerve runs backwards in company with the internal carotid artery in the parabasal canal, and joins the ramus hyoideus VII lateral to the posterior portion of the stapes.

The pterygoid is a fairly long, slender bone lying ventro-lateral close to the skull base from which it is separated by a layer of sparse connective tissue. Anteriorly the palatine fits firmly into a dorso-median groove of the pterygoid, whereas the posterior process of the maxillary lies in a ventral groove of the bone. The pterygoid at this level thus consists of two blades: the one vertically, and the other horizonto-medially inclined. A twist in the process of the maxillary results in the reversal of its relation to the pterygoid. The condition as described above ensures that any pressure exerted upon the pterygoid from behind will be transferred to the palatine and especially to the maxillary. The importance of this arrangement for the cranial kinesis need not be stressed. The ramus maxillaris V and the maxillary branch of the internal carotid artery are wedged between the pterygoid latero-dorsally, the palatine medio-dorsally and the maxillary ventrally (Fig. 6a). The pterygoid is prolonged forwards to within reach of the lacrimal, i.e. well into the nasal region. Further back the pterygoid is bent outwards and lies between the quadrate laterally and the basisphenoidal ridge medially. The relation of the pterygoid to the latter has already been discussed above. A strong ligament attaches the pterygoid to the quadrate, but there is no actual mutual articulation. Even so, movement of the pterygoid would automatically involve movement of the quadrate, since the latter moves only passively during cranial kinesis (Versluijs, 1912).

Judging from Fig. 5 of von Bedriaga's work (op. cit.), it appears that the *transversum* is a fairly well-developed element of the palate in *Amphisbaena*. Lakjer (1927) confirms von Bedriaga's work and he too considers the transversum as a notable element of the oral roof. In *Monopeltis* the bone is vestigial and underlies, as a slender rod, the posterior maxillary process. Posteriorly it twists towards the medial side of the maxillary and then lies dorsal to the pterygoid.

The anterior tip of each *palatine* fits into a short medially facing groove of the vomer of its side. The palatine then spreads outwards to form the trough-shaped roof of the choanal groove. As in the Skinks (de Villiers, op. cit. and Kingman, 1932) this trough is very deep; for *Lacerta* the reverse is true. The palatines flatten out posteriorly, causing the choanal grooves to disappear from section. The lateral flange of the palatine is extended dorsally above the maxillary to which it is joined by means of dense connective tissue (Fig. 6a).

From the above descriptions and from Fig. 2 it appears that the skeletal elements of the palate in *Monopeltis* form a complete roof for the oral cavity. This is brought about by the broad parasphenoid and palatines posteriorly and by the vomers, maxillaries and premaxillary anteriorly. The fissures between the rostrum and the palatines are covered by the trabeculae. Only two notable fissures or fenestrae are found on each side in the palatal roof: one is bounded by the ventral vestiges of the zona annularis in front and the vomer behind, and allows passage for the duct from the organ of Jacobson; the other is bounded medially by the vomer and laterally by the palatine process of the maxillary and through this fenestra the choana opens. The lateral squame of the vomer thus separates the choanal openings from the orifices of the organ of Jacobson. (Cp. Lakjer, 1927, for *Trogonophis*.) Although the pterygoids are widely separated, they are so closely applied to the parasphenoid that there is no inter-pterygoidal vacuity.

Fuchs (1908) maintains that " der primitive Gaumen entsteht durch Verwachsung der beiden Nasenfortsatze auf jeder Seite— . . . . . —Die primitiven Choanen beginnen unmittelbar hinter dem primitiven Gaumen; . . . ." Usually the premaxillaries form the only membrane bones of this primitive palate, but in *Monopeltis* the maxillaries and the vomers (cp. de Villiers, op. cit., for *Acontias*) extend forwards above the premaxillary into this region of the palate. The palatine processes of the premaxillary extend backwards ventral to the maxillaries, even beyond the orifices of the organ of Jacobson which, according to Fuchs (1908), form the posterior boundary for the primitive palate. The Saurian " sekundärer Gaumen " is formed in that region where the " Chaonenspalte " are closed by connective tissue and epithelium (cf. Fuchs, 1908). This secondary palate is very broad and long in *Monopeltis*. The extensive palatine processes of the maxillaries and of the premaxillary form a broad platform simulating the secondary palate of the Mammalian-Crocodilian type; this platform is merely the result of extension of the palatal portions of the above named bones. In this respect there is a close similarity between *Monopeltis* and the Scincidae. (Cp. de Villiers, op. cit. and Fuchs, 1908.) The " primitive Choane " extends for about 100μ beyond the choanal opening, and the " Vomerpolster " is represented by a broad ridge of connective tissue and epithelium situated between the choanal openings (Fig. 6a). Between the orifices of the organ of Jacobson the " Choanen-papille " (Fuchs), or papilla palatina, forms an extension of the " Vomerpolster." Concerning the orifices in *Lacerta;* Fuchs (1908) states: " Es mündet nämlich jedes Organ stets . . . . und zwar vermittelst des absteigenden Choanengangschenkels (as) in das hier beginnende vordere Ende der primitiven Choanen (pr. Ch.) aus." In the adult specimen of *Monopeltis* no corroboration of Fuch's assertion was possible, since there is no trace of the " primitive Choanen " at this level. The orbitonasal trough **is**

shallow and wide, and the choanal grooves do not join each other in an "Orbitonasalrinne" as in *Acontias*. (Cp. de Villiers, op. cit., and Fuchs, 1908.)

Glands of the Buccal Cavity.—In his work on the glands of the oral cavity, Fahrenholz (1937) states as follows in regard to the Amphisbaenidae: "Ober- und Unterlippendrusen (darunter Gl. dentales) und Gland. mandibulares sind vorhanden. Vomerdrüsen und Gaumendrüsen fehlen; uber Zungendrüsen und die anderen Drusengrupen ist nichts bekannt." The terminology of Fahrenholz will be adopted in the following account. I can confirm the author's statement that the glandulae vomerales and the gl. palatinae are absent in *Monopeltis*. The glandulae sphenopterygoideae are represented by a layer of goblet cells; these line the choanal grooves, but medially isolated glandular tubuli could also be made out. Although the glandulae linguales are absent as such, goblet cells are sparsely scattered over the upper and lateral surfaces of the tongue. The glandulae mandibulares are exceedingly well-developed glands lying medial to the lower jaw on either side in the anterior region; posteriorly. however, such groups of glands approach the middle line where they are separated by means of connective tissue.

Glandulae labiales inferiores are present on the lateral surface of the lower law, and the upper lip bears gl. labiales superiores. These latter are well-developed anteriorly and can be divided into glandulae dentales medially, and glandulae labiales propriae laterally. Posteriorly the glandulae labiales superiores are smaller, whereas the gl. labiales inferiores are well-developed in the form of three or more longitudinal groups of glands. The glandulae crico-arytenoideae are represented by folds in the ventral oral epithelium, but it could not be ascertained histologically whether such glandular crypts as the gl. crico-arytenoideae actually show secretory activity. Fuch's "Mundwinkeldrüse" (1932) is apparently not represented in *Monopeltis*.

The Otico-Occipital Region.—It has been noted above that the constitution of the otico-occipital region has been influenced by the fossorial life of *Monopeltis*. The posterior half of the skull is devoid of arcades, owing to the absence of the jugal, the postorbital, the postfrontal and of the much disputed bones of the temporal roof, the remaining bone being a small element of about 600μ in length. Brock (1941, p. 81) has noticed a similar condition in the skull of *Amphisbaena*, and states that "the general morphology of the skull is . . . . even more slender and lacking in angles and projections calculated to impede a subterranean existence." The cartilage bones of this region in *Monopeltis* are not massive and could not effectively support the nasal region during burrowing actions. This deficiency is supplemented by the fairly rigid connection between the parietal and the supraoccipital. The auditory apparatus has undergone a startling modification, expressed in the absence of a middle ear and in

the extraordinary development of the extra-columella. The quadrate assumes a horizontally inclined position and is decidedly streptostylic.

The parietal is a single median element constituting the larger part of the roof of the skull (Fig. 1). It possesses two short, blunt posterior processes, two anterior finger-like prongs overlying the frontals, and a lateral projection on each side, lying in a groove of the frontal (Fig.7). Behind the frontals the side walls of the cavum cranii are formed by the parietal which even comes into contact with the orbitosphenoids and the prootic extensions; this condition is brought about by downgrowths of the parietal similar to those of the frontals; the anterior side walls of the cavum cranii are therefore bony. The relation of the parietal to the frontals is such that the anterior half of the skull is movable against the posterior: a condition known as mesokinesis. Each frontal forms a medially facing trough for the lateral flanges of the parietal (Fig. 7). Since the connective tissue between the bony elements is very loose, the frontals can slide forwards and backwards over the flanges of the parietal. The finger-like prongs referred to above prevent the frontals from being dislocated. Behind the parietal foramen, the parietal forms a dome-shaped structure, in the ventral groove of which the processus ascendens tecti synotici (Gaupp) lies. This cartilaginous process is very short, and being rigidly attached to the parietal, it impedes movement of the latter over the supraoccipital. Fig 10a shows the anterior tip of the process which invades the parietal. Fig. 10b represents a section 200μ behind the latter; here the process has already partly co-ossified with the supraoccipital. The parietal is thus firmly anchored to the occipital segment of the skull. Moreover, the thin layer of connective tissue between the parietal and the supraoccipital and prootic bones is very dense. The condition described above would not necessarily prevent all movement in this region. *The parietal eye* is present in *Monopeltis*, but owing to the thickness of the sections, it was impossible to investigate the histological details. Generally, however, the organ appears to be well-developed. The parietal foramen is closed by means of connective tissue.

A number of longitudinal sensory grooves were found scattered all over the head, but histological details could not be studied. The presence of these grooves is probably associated with the loss of sight in the genus.

The temporal bones.—The homology of the bones of the temporal region of the Lacertilia has been the cause of considerable controversy ever since the works of Gaupp (1894) and of Thyng (1906) were published. Recently this problem has been discussed at length by Versluijs (1924), Broom (1935) and Brock (1935), and the reader is referred to their work for a detailed account. The terminology of Versluijs will be used in the present paper. (See Fig. 8.). The temporal region of *Monopeltis* has

undergone a remarkable change. Since only one small bony element is present, and arches and fossae are lacking, the skull may be regarded as gymnocrotaphic. (Cp. de Villiers, op. cit., for Acontias). The remaining temporal bone (Figs. 1 and 8) appears in section as a splint overlying the head of the quadrate and the crista parotica, but a dense tract of connective tissue separates it from these elements. Posteriorly it slants upwards towards the parietal and lies closely applied to the otic capsule. According to Broom (1924) and Brock (1935) the external adductor muscle (Lakjer, 1926) is always attached to the outer bone, and since this muscle is not inserted upon the bone in question in the skull of *Monopeltis*, this element represents undoubtedly the inner bone or supratemporal of Versluijs. Its topographic relations to the quadrate head, the crista parotica and the otic capsule is the same as that described by Brock (1935) for the inner bone. In this respect *Monopeltis* resembles the snakes where the inner element only is present (de Beer, 1937). Von Bedriaga (op. cit.) figures an os squamosum (i.e. inner bone) for *Amphisbaena cinerea*.

The quadrate in most Lacertilia projects outwards and downwards. In *Monopeltis* it is fairly long bone lying parallel to the otic capsule and to the prootic extension, being thus horizontally inclined as in *Amphisbaena*. (Cp. Lakjer, 1927.) The anterior (ventral) portion is knob-like and articulates on a concave facet with the lower jaw. Its posterior portion is more slender and forms a trough on the median side to harbour the m. depressor mandibulae. (Cp. Versluijs, 1898, for *Amphisbaena*). The head of the quadrate is covered with cartilage facing the articulatory cartilage of the crista parotica from which it is separated by means of a definite synovial joint. A separate intercalary could not be found, and it is probably incorporated in the crista parotica. A strong ligament attaches the quadrate to the pterygoid, and when the latter is moved by the contraction of the m. protractor pterygoidei, the quadrate would also be displaced forwards.

The auditory apparatus.—The different components of the auditory capsule are so intensely fused that there is no indication of the individual boundaries; even cartilaginous sutures are absent. The absence of the middle ear and of the Eustachian tube has obscured and complicated the relations of the auditory apparatus. The stapes is surrounded by large lymph spaces simulating the middle ear of other Lacertilia. (Cp. de Villiers, op. cit., for *Acontias*.). It is a bulky bony structure wedged in between the paroccipital process dorsally and the basisphenoidal ridge ventrally (Figs. 2 and 8). The broad footplate covers the foramen ovale completely and even overlaps the bones surrounding the foramen. Between the footplate and these elements definite synovial joints are found, indicating the possibility of movement of the stapes. The stapedial style is short and massive and fused to and co-ossified with the extra-columella. The latter,

in comparison with the rest of the skull, is strikingly large, its length being about three-sevenths that of the total head length (Fig. 2). In *Amphisbaena* and *Rhineura* there is an articulation between the extra-columella and the stapes (Versluijs, 1898, Lakjer, 1927 and Camp, 1923). In *Monopeltis* this cartilaginous bar passes forwards ventral to the quadrate and medial to the m. depressor mandibulae on to the lateral surface of the lower jaw. At this level it flattens out obliquely and becomes firmly attached to the epidermis of the lower jaw. Anteriorly a number of foramina and fissures are formed. Movement of the lower jaw would cause movement of the extra-columella, and since this structure is fused to the stapes, the latter would have to rotate in the foramen ovale. This theory is borne out by the presence of synovial joints between the footplate and the cranium. Sound-waves are probably transferred from the ground to the inner ear by means of the extra-columella.

The Nerves and Bloodvessels.

The facial and auditory nerves have a common ganglion situated within the cavum cranii. The facial nerve traverses the prootic through a foramen antero-ventral to the stapes, and immediately branches into the r. hyoideus and the chorda tympani. The r. palatinus branches off from the facial before the latter has traversed the prootic; the palatine nerve then runs ventrally in a canal in the prootic to join the internal carotid artery in the parabasal canal. The chorda tympani remains in front of the stapes as in *Amphisbaena* (cp. Versluijs, 1898), and turns laterally behind the tip of the pterygoid; it then runs forwards on the ventro-lateral side of the quadrate and the pterygoid, and enters the lower jaw in front of the articulatory facet. The relations of the chorda tympani to other elements in the lower jaw will be described below. The hyoid nerve passes backwards over the columella auris, and is joined by the commissural nerve from the r. palatinus.

The vena capitis lateralis lies dorsal to the stapes in a bony canal formed by the stapes medio-ventrally and the prootic dorso-laterally (Fig. 8). Anteriorly the vein lies medial to the quadrate. The internal carotid artery and the commissural nerve run forwards ventro-lateral to the stapes and enter the parabasal canal at the level of the anterior tip of the stapes.

The ninth and tenth nerves leave the skull through the foramen jugulare, but they are not fused as in *Amphisbaena* (cp. Versluijs, 1898). The n. accessorius and n. hypoglossus are separated from the two former by a bony partition in the fissura metotica; they themselves are separated by means of dense connective tissue.

The Lower Jaw.

The lower jaw of *Monopeltis* presents several points of interest. Only five of the membrane bones enumerated by Versluijs (1924) are present, the splenial being absent

as in *Sphenodon* (Versluijs, 1924). Von Bedriaga (op. cit.) recognised only four membrane bones in *Amphisbaena;* the gonial and splenial are apparently tacitly regarded as being absent, since their existence is not mentioned. In *Monopeltis* the dentaries do not form a bony symphysis, but are rigidly joined by means of connective tissue. A typical Lacertilian processûs coronoideus is formed by the coronoid. (See Fig. 9.)

Anteriorly Meckel's cartilage lies in a ventro-median groove of the dentary, while the ramus mandibularis V, the chorda tympani VII. a small bloodvessel and a splint of the supra-angular fit closely in a canal in the dentary, the latter forming a bony partition between the canal and the groove for Meckel's cartilage. Posteriorly this bony partition disappears and the cartilage then lies in the same canal as the nerves and the bloodvessel. In this region the dentary is gradually diminished in size until it is merely represented by a ventral splint. The r. mandibularis V and a branch of the internal carotid artery enter the above-mentioned canal through the fossa praearticularis, immediately anterior to which Meckel's cartilage ossifies as the os articulare, fusing intimately with the supra-angular dorsolaterally and with the gonial medially, and thus enclosing a large marrow cavity between them (Fig. 9). The chorda tympani VII enters the lower jaw through a foramen in the gonial, anterior to the articulatory facet, and proceeds forwards between the gonial and the articular, thus fixing the boundary between these two bones. Anteriorly the chorda tympani fuses with the r. mandibularis V. In the region of the fossa praearticularis the nervus auriculotemporalis passes from the r. mandibularis to the lateral side of the jaw through a foramen in the supra-angular as in *Acontias* (de Villiers, op. cit.). Despite its position, this foramen must be homologous with that situated between the supra-angular and the dentary as described by Fuchs (1931) for *Physignathus*.

A number of additional foramina occur anterior to the fossa praearticularis; one of these is situated in the angular and through it the nervus mylohyoideus passes to the musculus mylohyoideus. (Cp. Versluijs, 1921, and Fuchs, 1931). Small foramine in the dentary allow passage for viscero-sensory nerves to the tongue and for somatic-sensory nerves to the adjacent skin. The dentary bears seven pleurodont teeth, of which the anterior three are the larger. (Cp. von Bedriaga, op. cit., for *Amphisbaena cinerea*).

The movement of the lower jaw against the quadrate is facilitated by the presence of meniscal cartilages derived from the pars cartilaginea ossis articularis and from the pars quadrata palatoquadrati. The bony articulatory facet on the lower jaw is formed by the articular and the supra-angular, whereas the processûs retroarticularis is formed by the gonial and the articular. The angular does not reach to the suspensorial region (cp. de Villiers, op. cit., for *Acontias*): it is a small bone lying in a median groove of the dentary, ventral to Meckel's cartilage and its ossified

articular. Since the lower jaw articulates medio-ventrally with the quadrate, the supra-angular also partakes of the formation of the articulatory facet, and it is covered by cartilage derived from the pars cartilaginea ossis articularis, which is invaded by the supra-angular bone. Similar relations were described for *Amphibolurus barbatus* by Fuchs (1931). The position of the facet can best be seen in Fig. 9.

THE CRANIAL KINESIS.

According to Versluijs (1912 and 1924) the kinesis in the skull of the ancestors of the Sauropsida was of the type called metakinetic; this type of kinesis was present in the skull of the Diaptosauria. Metakinesis, briefly, is that condtion of the skull in which a line of flexure exists between the parietal and the supraoccipital; the maxillary segment, which includes the parietal, is then movable against the solid occipital segment. Versluijs maintains that this is the primary condition, and that it is represented among living forms in most of the Lacertilia. Under influence of a change of habits and diet, the posterior line of bending may be replaced by an anterior line which is usually situated between the parietal and the frontals, but it may be situated even further forwards. Should both lines of bending be present in the same skull, the condition is known as amphikinetic. A radical change in milieu, habits and diet may also result in the complete loss of kinesis and the skull would become akinetic. Of what use is a kinetic skull to an animal? According to Versluijs (1912) kinesis enables the animal to open its mouth wider; this serves the purpose of capturing fast moving prey—in the case of the Lacertilia usually insects—with greater ease and accuracy.

The kinesis in the skull of *Monopeltis* is of a most interesting type. It has been noted above that the pterygoids articulate with the basisphènoidal ridges by means of the intercalation of synovial joints. Contraction of the m. protractor pterygoidei displaces the pterygoids forward, and the streptostylic quadrate passively moves in the same direction. The pterygoids are rigidly joined to the palatines and the posterior processes of the maxillaries by means of interlocking processes and dense connective tissue, and any pressure exerted from behind upon the pterygoids will be transferred directly to the palatines and the maxillaries. The former of these convey such pressure to the vomers, and this mechanism is responsible for the discharging of the contents of the organ of Jacobson. Meanwhile, the maxillaries exert pressure upon the septomaxillaries and the nasals, and since the latter are firmly joined to the frontals by means of connective tissue and bony squames, the frontals will be pushed upwards and backwards The palatine processes of the maxillaries are in contact with the corresponding processes of the premaxillary, and the latter will therefore aid the nasals in pushing the frontals backwards. The final result of these movements is a lifting of the anterior region of the skull, the mouth being consequently opened wider. In *Monopeltis* as in *Amphisbaena* (Versluijs, 1912), the

mouth is situated antero-ventrally and would be of little practical use, were not the kinesis responsible for the lifting of the anterior portion of the skull, thus bringing the oral opening forwards and into a more favourable position. It will be noted that the ossa transversa are so vestigial that they do not participate actively in the kinesis. The frontal lamellae loosely clasp the lateral flanges of the T-shaped parasphenoid, and they can therefore slide forwards and backwards over these flanges (Fig. 7). The orbitosphenoids are placed in such a position that they will not impede the movement of the frontals. The peculiar formation of the prootic extensions and of the orbitosphenoids supplies a firm support for the nasal region, and at the same time prevents it from moving too far downwards when burrowing actions require a considerable amount of pressure. (See Fig. 10).

The articulation between the parietal and the frontals has been discussed above. The parietal is firmly anchored to the occipital segment by means of the short processûs ascendens tecti synotici and by means of a thin layer of dense connective tissue (Fig. 10). The transition from metakinesis to mesokinesis in *Monopeltis* is caused by the necessity of supplying a firm support for the nasal region; the frail structure of the cartilage bones of the occipital segment is counteracted by the anchorage of the parietal to this segment, but such anchorage would not bring about total loss of bending in the posterior line, and it may be assumed that the parietal is able to move backward and forward over the supraoccipital and prootic bones to a certain extent. It will now be clear that the skull of *Monopeltis* has advanced slightly beyond the amphikinetic stage; the transition from metakinesis to the fully mesokinetic condition must have taken place along similar lines.

The phylogenetic position of the Amphisbaenidae has always been a vexed problem. These animals are so specialised and at the same time so degenerate, that it is difficult to connect them with any other group of the Lacertilia. Undoubtedly they represent a very old group, as is shown by the discovery of fossil remains in the Oligocene of North America (cp. Camp, op. cit.), and by the wide distribution of the living representatives. Their cranial anatomy exhibits several points of similarity with that of snakes, e.g. the platytrabic condition, the formation of a cranial box by means of the lamellae of the frontals and the parietal, the gymnocrotaphic temporal roof, and the mesokinetic line of bending. The vestigial eyes and optic nerves, the absence of the eye muscles and their corresponding nerves, and the extraordinary transformation of the auditory apparatus render it very unlikely that any direct relationship can exist between the snakes and the Amphisbaenidae. The resemblance in cranial anatomy of these forms is probably due to parallel evolution as an adaptation to fossorial habits.

Summary.

As might be expected from a fossorial form, the skull of *Monopeltis capensis capensis* Smith differs considerably from that of other Lacertilia; the fossorial life has, in fact, been the cause of nearly all the deviations in the skull from the standard Lacertilian pattern.

The chondrocranium exhibits progressive degeneration, as is indicated by the vestigial lamina transversalis anterior, paraseptal cartilages and pp. maxillares anteriores and posteriores, and by the absence of the cart. alaris superior and the taeniae. The orbitosphenoids probably ossify in the pila metoptica and the planum supraseptale.

The interorbital septum is very short and bifurcates into the paired trabeculae immediately behind the cartilaginous nasal capsule; the skull is therefore platytrabic as in the snakes.

The organ of Jacobson is fairly well-developed, but the orifices are very small and a considerable amount of pressure would have to be exerted before the contents of the organ could be discharged into the oral cavity.

Only a few of the glandular areas described by Fahrenholz for the Lacertilia are present; glandulae vomerales, palatinae, sphenopterygoideae, linguales and circo-arytenoideae are absent.

The bony oral roof is complete, being formed by the extensive palatal squames of the fused premaxillaries, the maxillaries, the vomers, the palatines and the broad parasphenoid. The parasphenoid, basisphenoid and basioccipital are completely fused. Basipterygoid processes are absent, but synovial joints are formed between the meniscal cartilages on the pterygoids and the cartilaginous basisphenoidal ridges. The quadrate articulates with the crista parotica and is horizontally inclined. Epipterygoids are lacking.

The orbital region is very short, owing to the enlarged occipital segment of the skull. The eyes and optic nerves are vestigial, and the eye muscles and their nerves are absent. A lacrimal bone and a nasolacrimal duct are present, but the jugal, prefrontal, postfrontal and postorbital are lacking. The frontals are very short and belong topographically to the nasal region.

The temporal region is devoid of arches and fossae, since a single small supratemporal bone is present; the skull, therefore, is gymnocrotaphic.

Downgrowths of the frontals and of the parietal form a solid cranial box for the brain as in the snakes.

The parietal foramen is closed by means of connective tissue, and the parietal eye appears to be well-developed.

The auditory apparatus has undergone striking changes. The stapes is very large and is movably connected with the cranium,

synovial joints being developed. The extra-columella is a bulky cartilaginous bar fused to the stapes and lying lateral to the lower jaw. A middle ear and Eustachian tube are absent.

The lower jaw is typically Lacertilian, but the splenial is absent. The articulatory facet is medio-ventrally situated. The teeth are roughly pleurodont.

The skull is mesokinetic; the parietal is joined to the occipital segment to strengthen the latter, and the line of bending is situated between the frontals and the parietal.

In conclusion of this paper, I would like to express my sincerest gratitude to Professor C. G. S. de Villiers, whose constant guidance and criticism have been of invaluable assistance.

REFERENCES.

1884 BEDRIAGA, J. VON: "*Amphisbaena cinerea* Vand und A. Strauchi v. Bedr. Erster Beitrag zur Kenntniss der Doppelschleichen." *Arch. Naturges.*, **50:** 23 (1884).

1910 BOULENGER, G. A.: "A Revised List of the S.A. Reptiles and Batrachians." *Ann. S.A. Mus.*, **5:** 455 (1910).

1935 BROCK, G. T.: "The Temporal Bones in Lizards, Birds and Mammals." *Anat. Anz.* **80:** 266 (1935).

1941 BROCK, G. T.: "The Skull of *Acontias meleagris*, with a Study of the Affinities Between Lizards and Snakes." *Linn. Soc. Journ.—Zool.* **41:** 71 (1941).

1919 BROMAN, I.: "Das Organon vomero-nasale Jacobsoni—ein Wassergeruchsorgan." *Anat. Hefte*, **174:** 143 (1919).

1924 BROOM, R.: "On the Classification of the Reptiles." *Bull. Amer. Mus. Nat. His.* **51:** 39 (1924).

1935 BROOM, R.: "On the Structure of the Temporal Region in Lizard Skulls." *Ann. Tr. Mus.* **18:** 14 (1935).

1935 BROOM, R.: "The vomer-parasphenoid question." *Ann. Tr. Mus.*, **18:** 23 (1935).

1910 BUTSCHLI, O.: Vorlesungen über vergleichende Anatomie. *Berlin.* (1910).

1923 CAMP, C. L.: "Classification of the Lizards," *Bull. Amer. Mus. Nat. His.*, **48:** 289 (1923).

1892 COPE, E. D.: "The Osteology of the Lacertilia." *Proc. Amer Phil. Soc.*, **30:** 185 (1892).

1937 DE BEER, G. R.: "The Development of the Vertebrate Skull." *Oxford University Press* (1937).

1939 DE *Villiers*, C. G. S.: „Uber den Schädel des südafrikanischen schlangenartigen Scinciden *Acontias meleagris*." *Anat. Anz.* **88:** 289 (1939).

1937 FAHRENHOLZ, C.: „Drüsen der Mundhöhle." *Bolk-Göppertsches Hdb. d. vergl. Anat. d. Wirb.*, **3:** 115 (1937).

1908 FUCHS, H.: „Uber das Munddach der Rhyncocephalen, Saurier, Schlangen, Krokodile und Säuger und den Zusammenhang zwischen Mund- und Nasenhöhle bei diesen Tieren." *Zts. f. Morph. u. Anthr.*, **11:** 153 (1908).

1931 FUCHS, H.: „Uber das Os articulare mandibulae bipartitum einer Echse (*Physignathus Lesueurii*)." *Morph Jhrb.*, **67:** 318 (1931).

1932 Fuchs, H.: „Von dem Ductus angularis oris einiger Schildkröten (*Podocnemis expansa; Emys europaea; Chelone imbricata*)," *Morph. Jhrb.*, **71**: 436 (1932).

1894 Gaupp, E.: „Beiträge zur Morphologie des Schädels: III Zur vergleichende Anatomie der Schläfengegend am knöchern Wirbeltirschädel." *Morph. Arb.*, **4**: 77 (1894).

1900 Gaupp, E.: „Das Chondrocranium von *Lacerta agilis*." *Anat. Hefte*, **14**: H.3: 435 (1900).

1825 Gray, J. E.: "A Synopsis of the Genera of Reptiles and Amphibia, with a description of some new species." *Ann. Philosophy* (*2*), **10**: 193 (1825). (Cited from Loveridge, op. cit.).

1865 Gray, J. E.: "A Revision of the Genera and Species of Amphisbaenians with the descriptions of some new species now in the British Museum." *Proc. Zool. Soc.* London, 442 (1865).

1932 Kingman, R. H.: "A Comparative Study of the Skull in the Genus Eumeces of the Family Scincidae." *Bull. Univ. Kansas*, **33**: 273 (1932).

1926 Lakjer, T: „Studien über die Trigeminus-versorgte Kaumuskulatur der Sauropsiden." *Reitzels Verlag, Kopenhagen* (1926).

1927 Lakjer, T.: „Studien über die Gaumenregion bei Sauriern im Vergleich mit Anamniern und primitiven Sauropsiden. *Zool. Jhrb.* (*Abt. Anat.*), **49**: 57 (1927).

1941 Loveridge, A.: "Revision of the African Lizards of the Family Amphisbaenidae." *Bull. Mus. Comp. Zoöl. Harvard College*, **87**: 353 (1941).

1940 Malan, M. E.: "Cranial Anatomy of the Genus Gerrhosaurus." *This Journal*, **37**: 192 (1940).

1936 Parker, H. W.: "Dr. Karl Jordan's Expedition to South-West Africa and Angola: Herpetological Collections." *Nov. Zool.* **40**: 115 (1936).

1940 Parrington, F. R. and Westoll, T. S.: "On the Evolution of the Mammalian Palate." *Phil. Trans. Roy. Soc. London, Series B*, **230**: 305 (1940).

1898 Peter, K.: „Die Entwicklung und funktionelle Gestaltung des Schädels von *Ichthyophis glutinosus*." *Morph. Jhrb.*, **25**: 555 (1898).

1867 Peters, W.: „Uber eine Sammlung von Flederthieren und Amphibien aus Otjimbingue in Südwestafrica, welche Hr. Missionär Hahn dem zoologischen Museum zugesandt hat." *Monatsb. Akad. Wiss. Berlin*, 234 (1867). (Cited from Loveridge, op. cit.).

1885 Smalian, C.: „Beiträge zur Anatomie der Amphisbaeniden." *Zts. f. wiss. Zool.*, **42**: 126 (1885).

1849 Smith, A.: Illustrations of the Zoology of South Africa. *London* (1849).

1856 Stannius, H.: Handbuch der Zootomie, II. *Berlin* (1856).

1906 Thyng, F. W.: „The Squamosal Bone in Tetrapodous Vertebrata." *Tufts Coll. Stud.*, **2**: 35 (1906).

1898 Versluijs, J.: „Die mittlere und äussere Ohrsphäre der Lacertilia und Rhyncocephalia." *Zool. Jhrb.* (*Abt. Anat.*), **12**: 161 (1898).

1912 Versluijs, J.: „Das Streptostylie-Problem und die Bewegungen im Schädel bei Sauropsiden." *Zool. Jhrb. Suppl. XV*, **2**: 545 (1912).

1924 Versluijs, J.: „Leerboek der vergelijkende ontleedkunde van de Vertebraten." *Oosthoek, Utrecht* (1924).

1936 Versluijs, J.: „Kranium und Visceralskelett der Sauropsiden." *Bolk-Göppertsches Hdb. d. vergl. Anat. d. Wirb.*, **4**: 775 (1936).

1944 Zangerl, R.: "Contributions to the Osteology of the Skull of the Amphisbaenidae." *The American Midland Naturalist*, **31**: 417 (1944). (Received too late for consultation).

LEGENDS TO THE FIGURES AND ABBREVIATIONS.

Fig. 1: Graphical reconstruction of the skull of *Monopeltis*—dorsal aspect. Extra-columella not reconstructed. ×25.

Fig. 2: Graphical reconstruction of the skull of *Monopeltis*—ventral aspect. Right extra-columella and teeth not reconstructed. ×25.

Fig. 3: Graphical reconstruction of the cartilaginous nasal capsule of *Monopeltis*—ventral espect. ×25.

Fig. 4: Transverse section through anterior nasal region of *Monopeltis*.

Fig. 5: Transverse section through organ of Jacobson in *Monopeltis*.

Fig. 6a: Transverse section through orbital region of *Monopeltis*.

Fig. 6b: Transverse section through orbital region of the snake *Homalosoma lutrix*.

Fig. 7: Transverse section through orbital region of *Monopeltis* in the mesokinetic line of bending.

Fig. 8: Transverse section through auditory apparatus of *Monopeltis*.

Fig. 9: Consecutive transverse sections through the suspensorial region of *Monopeltis*.

Fig. 10: Consecutive transverse sections through the metakinetic line of bending in *Monopeltis*.

Abbreviations.—art., artery accompanying ramus medialis nasi; b. occ., basioccipital; b. sph., basisphenoid; b. sph. r., basisphenoidal ridge; c. al. inf., cartilago alaris inferior; c. ecto., cartilago ectochoanalis; ch. gr., choanal groove; ch. op. choanal opening; ch. t., chorda tympani VII; comm. p. h., commissural nerve between the ramus hyoideus and the ramus palatinus VII; con. nas., concha nasalis; c. para., cartilago paraseptalis; cr. par., crista parolica; cup. ant., cupolae anterior; d. nph., ductus nasopharyngeus; dor. pr. mx., dorsal process of the maxillary; d. p. sph., dorsal splint of the parasphenoid; ex. col., extra-columella; ext. nar. op., external narial opening; fen. lat., fenestra lateralis; fen. nar., fenestra narina; fen. olf. eveh., fenestra olfactoria evehens; fen. sup., fenestra superior; for. ap., foramen apicale; for. ep., foramen epiphoniale; for. cup. ant., foramen in the cupola anterior; for. jug., foramen jugulare; for. mag., foramen magnum; fr., frontal; fr. lam., frontal lamella; gl. dent., glandulae dentales; gl. lab. pro., glandulae labiales propriae; gon., gonial; har. gl., Hardeian gland; i. car. art., internal carotid artery; i. orb. sep., inter-orbital septum; lac., lacrimal; m. cav., marrow cavity; nas., nasal; nas. sac., nasal cavity; n. prof., nervus profundus V; occ. cond., occipital condyle; O.J., organ of Jacobson; o. o. J., orifice of the organ of Jacobson; orb. sph., orbitosphenoid; os. art., articular; pal., palatine; pal. pr. mx., palatine process of the maxillary; pal. pr. pmx., palatine process of the premaxillary; pal. sq. mx., palatal squame of the maxillary; par., parietal; par. for., parietal foramen; p. c. o. a., pars. cartilaginea ossis articularis; pmx., premaxillary; p. mx. ant., processus maxillaris anterior; p. mx., post., processus maxillaris posterior; p. pr. mx., posterior process of the maxillary; p. q. pq., pars quadrata palatoquadrati; pr. as. t. syn., processus ascendens tecti synotici; pr. fr., processus frontalis; pro., prootic; pro. ext., prootic extension; p. sph., parasphenoid; p. sph. ros., parasphenoidal rostrum; ptg., pterygoid; qua., quadrate; r. hy., ramus hyoideus VII; r. max., ramus maxillaris V; r. med. nas., ramus medialis nasi; r. pal., ramus palatinus VII; s. ang., supra-angular; sep. nas., septum nasi; s. mx., septomaxillary; s. occ., supraoccipital; st. stapes; s. temp., supratemporal; sut. c., sutural cartilage; syn., synovial joint; t., tooth; tec. nas., tectum nasi; trb., trabeculae; tv., transversum; v., veins; v. c. l., vena capitis lateralis; VIII, auditory nerve; vo., vomer; Vo. p., "Vomerpolster"; V. p. sph., ventral splint of the parasphenoid; z. a., zona annularis.

FIG. 1

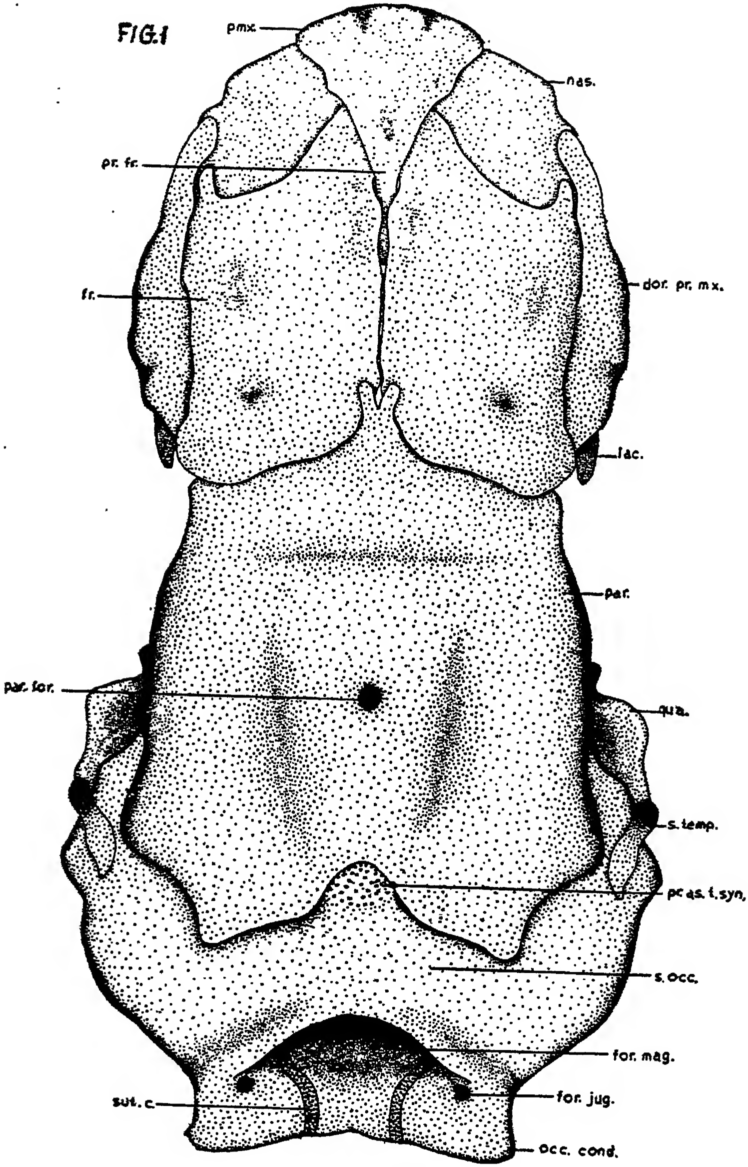
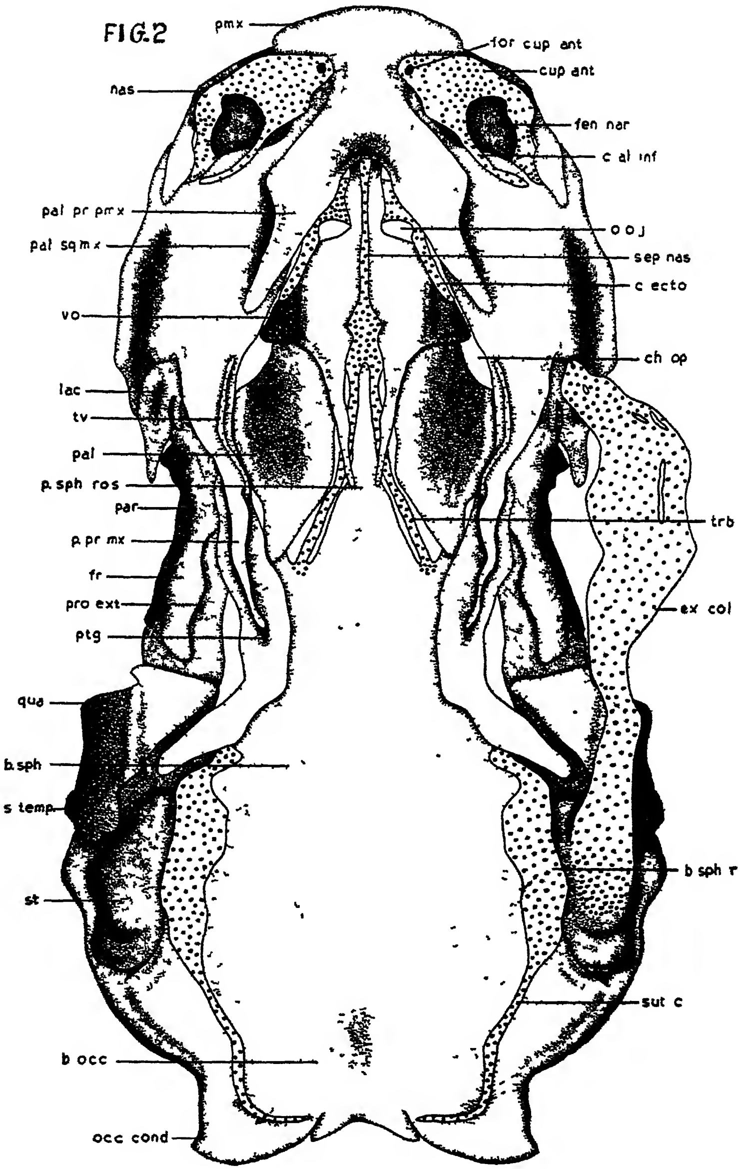
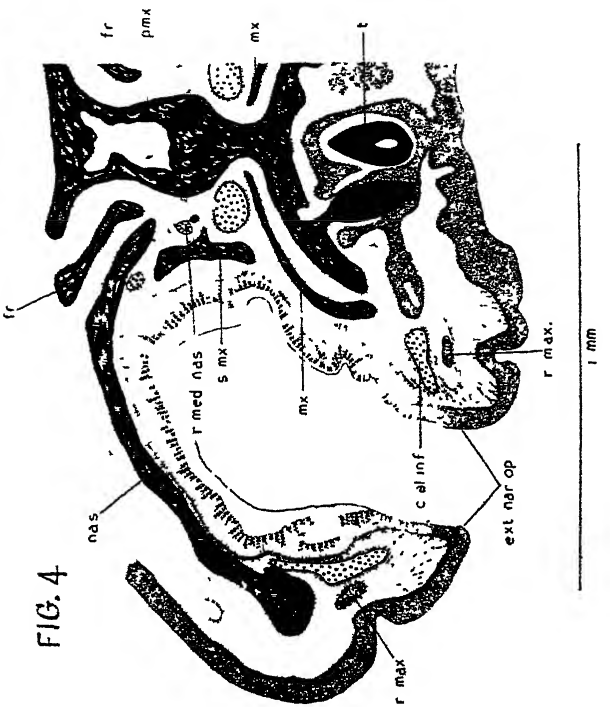

pmx.
nas.
pr. fr.
fr.
dor. pr. mx.
lac.
par.
par. for.
qua.
s. temp.
pr. as. t. syn.
s. occ.
for. mag.
for. jug.
sut. c.
occ. cond.

FIG. 2


pmx
for cup ant
cup ant
nas
fen nar
c al inf
pal pr pmx
o o j
pal sq mx
sep nas
c ecto
vo
ch op
lac
tv
pal
p. sph ros
par
trb
p. pr mx
fr
ex col
pro ext
ptg
qua
b. sph
s temp.
b sph r
st
sut c
b occ
occ cond


fr
pmx
mx
t
fr
r med nas
s mx
mx
nas
c al inf
ext nar op
r max.
r max
1 mm
FIG. 4

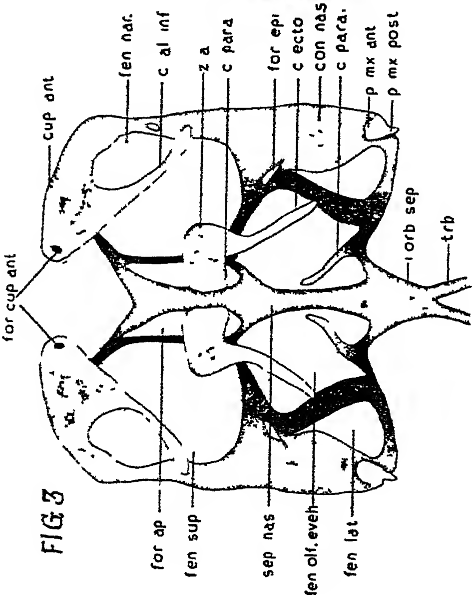
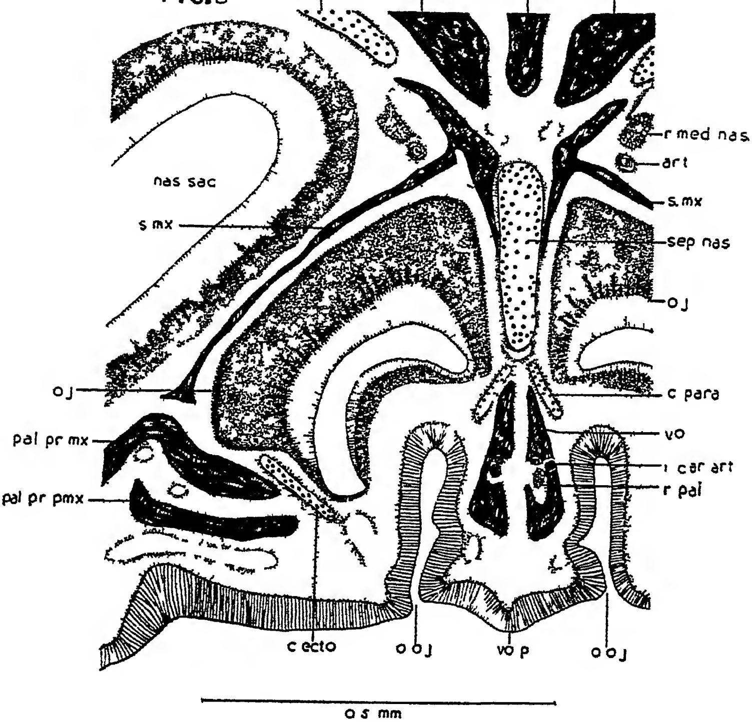
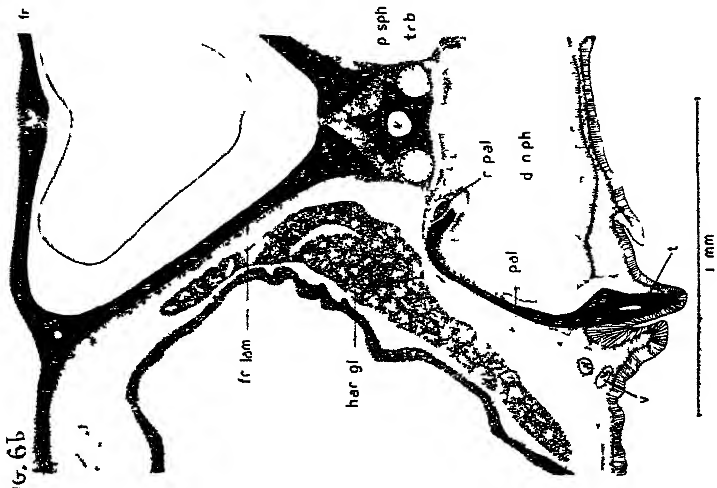

for cup ant
cup ant
fen nar.
c al inf
z a
c para
for epi
c ecto
con nas
c para.
p mx ant
p mx post
orb sep
trb
for ap
fen sup
sep nas
fen olf. eveh
fen lat
FIG 3

FIG. 5


tec nas
fr
pmx
fr
r med nas
art
s mx
sep nas
o j
c para
vo
i car art
r pal
nas sac
s mx
o j
pal pr mx
pal pr pmx
c ecto
o o j
vo p
o o j
0.5 mm


fr
p sph
trb
v
r pal
d nph
pal
t
fr lam
har gl
v
1 mm
fr
FIG. 6b

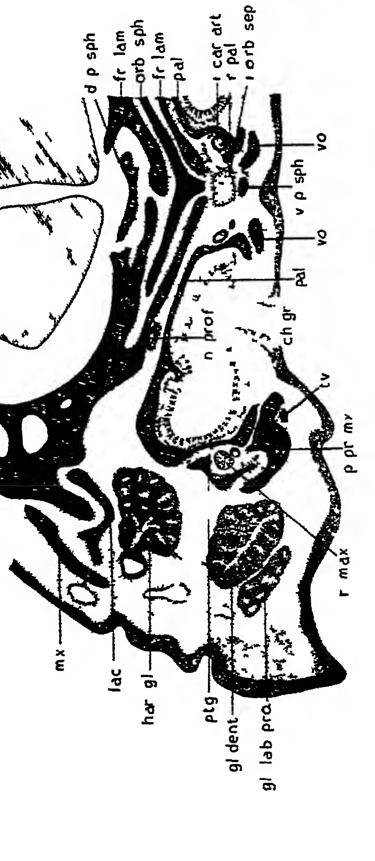

par
fr
fr
d p sph
fr lam
orb sph
fr lam
pal
i car art
r pal
i orb sep
vo
v p sph
vo
pal
ch gr
n prof
tv
p pr mx
r max
mx
lac
har gl
ptg
gl dent
gl lab pro
FIG. 6a

FIG. 7

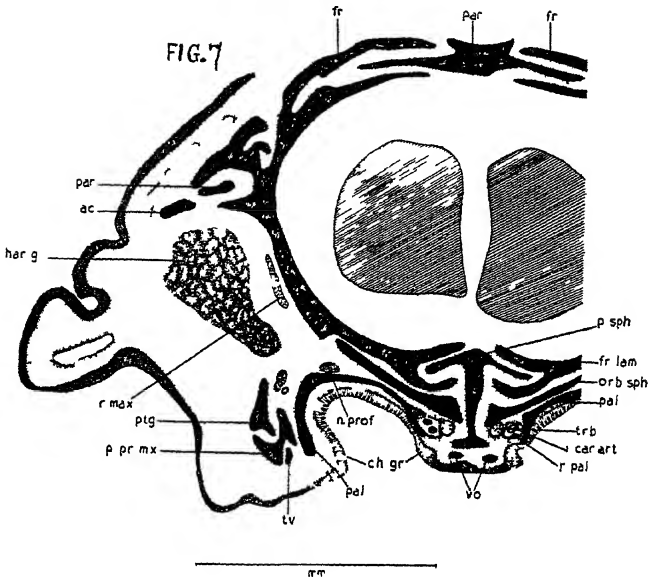
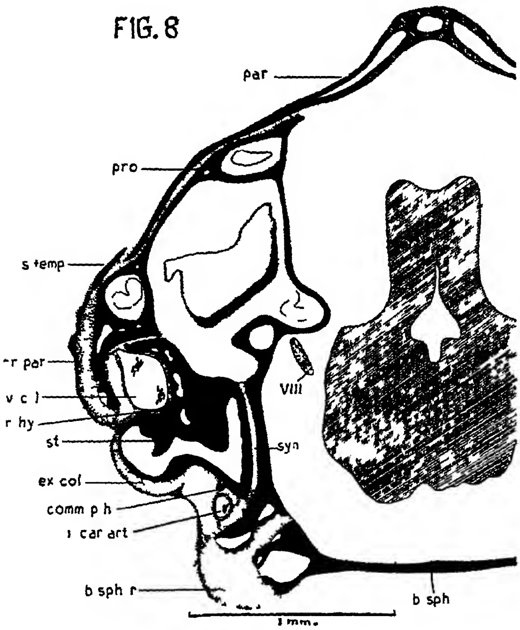

fr
par
fr
par
ac
har g
p sph
fr lam
orb sph
pal
r max
ptg
n prof
trb
car art
p pr mx
ch gr
r pal
pal
vo
tv
mm

FIG. 8


par
pro
s temp
r par
v c l
VIII
r hy
st
syn
ex col
comm p h
car art
b sph r
b sph
1 mm.

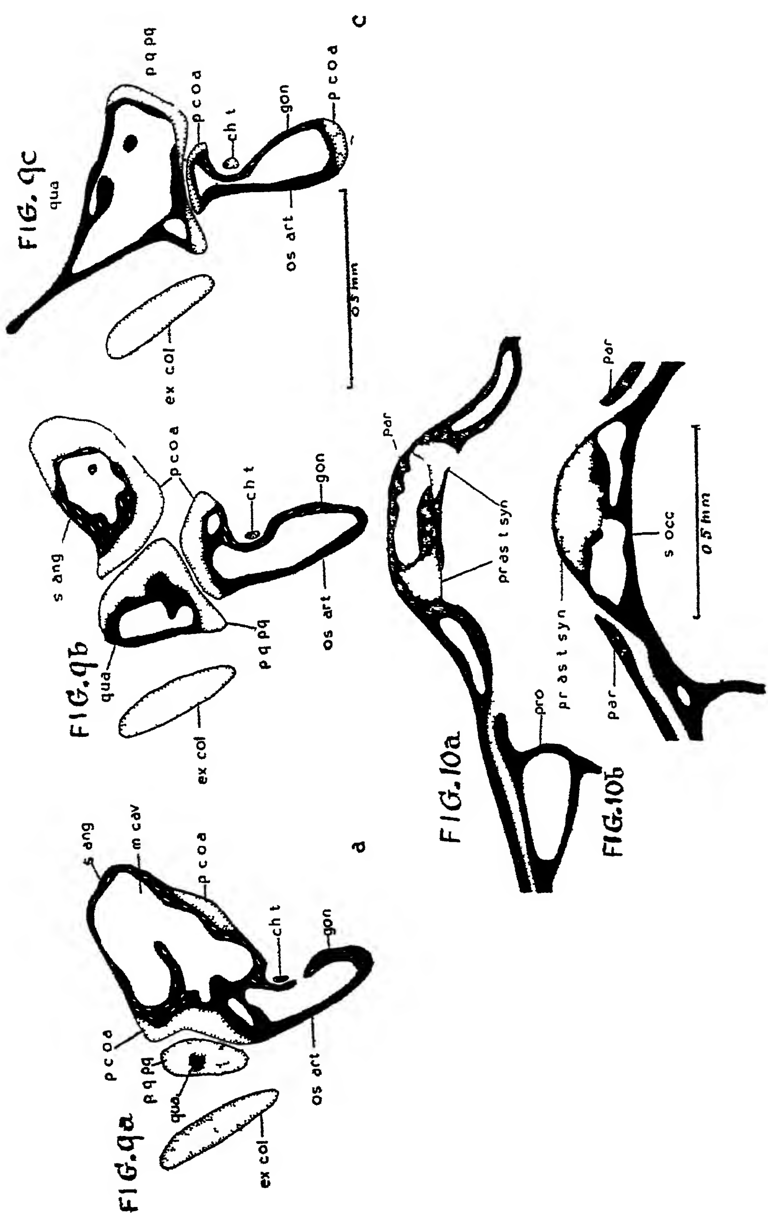


FIG. 9a
FIG. 9b
FIG. 9c
FIG. 10a
FIG. 10b
a
c
s ang
m cav
p c o a
ch t
gon
os art
p q p q
qua
ex col
0 5 mm
par
pro
pr as t syn
s occ

South African Journal of Science, *Vol. XLII, pp. 205-218, June, 1946.*

THE PROBLEM OF VITAMIN BALANCE IN AFRICAN DIETS

BY

Dr. L. Golberg, M.Sc., D.Phil., A.R.I.C.,
Biochemical Department, South African Institute for Medical Research.

Read 3rd July, 1945.

The balance of vitamins in African diets, particularly of the B complex vitamins, is a question of paramount importance in studying the aetiology of the deficiency diseases observed in Africans. It must play some part too, although imperfectly understood at the present time, in the genesis of a number of other diseases to which the inhabitants of this continent are subject.

In order to access the effects of disturbing influences upon vitamin balance, it is necessary to analyse some of the factors which go to make up an adequate African diet. This paper is intended to deal with two groups of basic foodstuffs—cereals and legumes, to discuss their value as sources of B vitamins, and to demonstrate the effects of milling, cooking and fermenting these foodstuffs.

It should be emphasised that this must be regarded as a preliminary communication on the subject. Nevertheless it is hoped that the data given will provide some quantitative basis for the common observation that the transition from primitive tribal life to peri-urban and urban conditions is frequently accompanied by a significantly increased incidence of deficiency disease. It is not implied that such deficiencies do not occur in Africans far removed from civilisation; or that the factors discussed here are the only, or even the chief, factors which make for frank malnutrition. It is probable that the balance of vitamins in the primitive diet is delicate and precarious at the best of times. The examples to be given here will serve merely to illustrate how easily the scales can be tipped in the wrong direction.

I—Cereals.

Whole Cereals.—The African diet is based largely on cereals and in order to meet calorific requirements an intake of about 2 lb. daily is necessary for an adult. The contribution made in other directions by these much-maligned foodstuffs is considerable. In fact they constitute the main source of B vitamins for the African. Their value in this respect is clearly shown in Table I.

TABLE I—Amounts of B Vitamins Provided by 2 lb. of Uncooked Whole Cereal.

Whole Cereal.	Amount of Vitamin in mgm. per 2 lb.		
	Thiamin.	Ribo-flavin.	Nicotinic Acid.
Maize (*Zea mays*)	2·8	1·15	16
Kaffir-corn (*Sorghum vulgare*)	2·7	1·0	28
Sweet sorghum (*Sorghum saccharatum*) ...	2·3	1·0	21
Millet, finger (*Eleusine coracana*) ...	1·6	1·0	8
Millet, bulrush (*Pennisetum typhoideum*)	2·8	1·3	19
Millet, pearl (*Pennisetum glaucum*) ...	3·0	—	—
Wheat (*Triticum vulgare*)	3·0	1·2	40
Rice (*Oryza sativa*)	3·4	1·2	31
Daily Requirements (see text below) ...	1·0	1·5	10

It will be seen in Table I that the daily requirements of thiamin, riboflavin and nicotinic acid have been taken as 1·0, 1·5 and 10 mg., respectively. These levels are admittedly not optimal; on the other hand some allowance must be made for intestinal biosynthesis of these vitamins. The levels taken do, however, serve to bring out the fact that the cereals, in the form of the original grain are to a large extent capable of meeting these requirements. Comparison of the other cereals in Table I with wheat and rice shows a noteworthy inferiority only in respect of nicotinic acid.

The actual daily consumption of cereals by Africans is of course very variable. It is probably in the region of 2 lb. when rations are provided by an employer. But under tribal conditions the average daily consumption over the whole year may be nearer 1·5 lb. or even less. Under these circumstances the amount of riboflavin available from most cereals becomes inadequate and nicotinic acid intake is drastically reduced.

Milling of Cereals.—In order to judge the value of these cereals as usually consumed, the effects of milling must be given careful consideration.

The primitive equipment available in the African kraal for milling and sifting cereals results in the inclusion of a considerable proportion of bran and germ in the meal. To prepare a finely sifted meal calls for considerable effort which is only expended for special occasions such as festivals; or, if many hands are available, as at a chief's kraal, the meal produced, fine though it be, yet possesses almost the whole nutritive value of the original grain. These and other facts which cannot be elaborated here are reflected in our findings on the thiamin content of African milling products (Table II).

TABLE II—Amount of Thiamin Provided in 2 lb. of Uncooked African Milling Products.

Milling Product.	Thiamin Content in mg. per 2 lb. Maize.	Kaffir-corn.	Kaffir-corn, Chief's Kraal.
Original Whole Grain	2·6	3·4	3·9
First Grinding or Stamping and Sifting	2·4	3·1	3·4
Husks from First Sifting ...	2·9	4·3	4·7
Second Grinding or Stamping and Sifting	2·2	2·7	3·3
Husks from Second Sifting ...	2·8	—	—
Third Stamping (Special) ...	2·0	—	3·2

Milling by European mills presents an entirely different picture. Although numerous small mills are in existence, the bulk of milling products purchased in South Africa, as possibly in other parts of Africa, issues from a small number of large and efficient mills. Under peace-time conditions such mills have to cater for a demand for highly refined meals to satisfy exacting human consumers and a demand for milling by-products for animal feeds. The division made, as can be seen from Table III, is that to a large extent the carbohydrates go to man, the vitamins and other nutrients to the animal. In South Africa government war-time regulations prohibit the production of meals of extraction lower than No. 1 Sifted mealie-meal (approx. 90 per cent. extraction). The effect of these measures on the thiamin intake of consumers can be judged from Table III.

TABLE III—Amounts of Thiamin Provided by 2 lb. of Milling Products from European Mills.

Product.	Extraction per cent.	Vitamin Content (mg./2 lb.). Thiamin.	Ribo-flavin.	Nicotinic Acid.
Unsifted Crushed Maize	100	2·8	1·1	18
Unsifted Mealie Meal	100	2·6	1·05	17
Sifted Crushed Maize	90—95	2·5	0·95	15·5
Fine Granulated Mealie Meal ...	90—95	2·5	0·9	15
Special or No. 1 Mealie Meal ...	60—70	1·7	0·5	14
Samp	60—65	0·5	0·4	7·5
Mealie Rice	60	0·4	0·35	7
Maize Flour	40	0·4	—	—
Bran	—	1·9	2·7	27
Maize Germ Meal	—	5·8	3·0	62·5
Hominy Chop	—	2·9	—	—
Grits	—	0·3	—	—

The data in Tables II and III demonstrate the effect on the consumer of a change-over to refined milled products. The ever more prevalent practice among Africans of selling their cereal crops and purchasing refined milling products in return, involves an economic loss; but in addition it results in a decreased vitamin intake which war-time restrictions on the production of refined meals have done much to remedy.

A further point worthy of mention is the subject of samp and mealie rice. These are the names given to fragments produced by cracking the endosperm after removal of the germ and bran, together with their valuable adhering aleurone layer and scutellum. Samp and mealie rice, consisting as they do of almost pure starch, are ideally suited for inducing multiple vitamin B deficiency (Table III.) Nevertheless these foodstuffs cannot be lightly discarded since they play an important part in providing some alleviation of the monotony of a diet composed predominantly of maize. Their popularity among the poor of all races would make it necessary to provide some equally cheap and tasty substitute if their production was to be prohibited. In our studies on maize milling products we encountered samples of mealie rice of 85 to 90 per cent. extraction containing about 2·1 mg. thiamin per 2 lb. These samples resembled kraal "milling" products in appearance. If generally acceptable, they might provide the solution of the difficulty.

One substitute for samp and mealie rice which is available in normal circumstances is rice. The values for whole rice were included in Table I. The rice commercially available in South Africa and East Africa has invariably been found to be polished. The same applies to rice imported from South America. The criterion of polishing generally accepted is the degree to which the grains of the cereal stain with Gram's iodine. By this means it is found that even the so-called "brown rice" is a polished form. Thiamin and riboflavin assays provide a striking confirmation of this observation. Whereas 2 lb. whole rice contain 3·8 mg. thiamin and 1·25 mg. riboflavin, the same weight of white or brown rice contains 0·85 mg. thiamin and 0·25 mg. riboflavin. Nicotinic acid, being more evenly distributed through the grain is still present in a concentration of 29 mg. in 2 lb.

Not only is the consequence of using rice, samp and mealie rice serious in itself, it is also serious in that the foods are regarded as *vegetables* and in the diet of the urbanised African they tend to replace the valuable legumes and leaves so widely employed in the tribal dietary. Dr. Fox, who drew our attention to this point, remarked that the use of samp and rice as vegetables is even more prevalent among Eurafricans and Europeans.

II—Legumes.

Ranking high among the items which help the African to consume an otherwise monotonous diet are beans and other

legumes, together with the relishes prepared from their leaves and pods. Barker (1943), describing food habits in Nyasaland, has thus extolled the virtues of a sauce made from groundnuts and cooked leaves:—

"It is this sauce which 'makes' the dish in the eyes of the African. Into it he can dip a seemingly never-ending succession of small lumps of *nsima* (maize meal porridge) which he proceeds to swallow until he reaches the blessed state of repletion, the goal of every meal. If groundnuts have not been added the lumps of *nsima* are duly dipped, but the sauce neither tastes well nor sticks satisfactorily to the lumps. Hence the meal is soon at an end, a large amount of *nsima* is left over and hunger is only temporarily appeased."

In addition to their action as appetisers, or perhaps because of it, legumes are regarded by the African as a substitute for meat. The flavour of beans is, however, of paramount importance. It is this consideration which in Native territories leads to such careful selection of seed, giving rise to strange varieties maintained in a state of purity with a care not encountered elsewhere.

Our study of the thiamin content of dry beans and other legumes (Golberg, Thorp and Sussman, 1945) has provided some interesting results (Table IV). Most legumes are far superior to cereals as dietary sources of thiamin, as they are of protein and often of fat. However the range of variation in thiamin content, from 1·82 to 13·80 μ g./g., emphasises the need for accurate knowledge concerning these foodstuffs. Out of 21 different kinds of dry legumes studied six were of approximately the same thiamin content as most of the cereals grown in Africa. Of these six, the two lowest, sugar beans and jugo beans are very popular among Africans. On the other hand the equally popular groundnut stands high on the list. The table also reveals that from the point of view of thiamin, there is some justification for the often widespread consumption by Africans of sword beans, velvet beans and other legumes usually regarded by Europeans as suitable only for fodder.

Data on the content of other B vitamins in legumes is as yet very incomplete. Nevertheless it is clear that groundnuts, containing approximately four times as much riboflavin and nicotinic acid as most cereals, and already very popular among Africans, constitute a ready means of restoring vitamin balance to the diet (see Table IV).

Thus far the discussion of legumes has been confined to the dry seeds. As indicated previously, their part in nutrition goes considerably further, for the African makes use of the leaves and young pods in the manner which puts the European to shame for his neglect of these valuable foods. For valuable foods they are, as indicated by the analyses we have so far been able to make (Table V, page 211).

TABLE IV—The Thiamin Content of Legumes.

Legume.		Thiamin Content µ g./g.
Scientific Name.	Common Name.	
Pisum sativum	Garden or Field Pea ...	9·70
Arachis hypogea	Groundnut	8·36
Glycine hispida	Soya Bean	6·81
Cajanus cajan	Pigeon Pea	5·89
Vigna unguiculata	Cowpea or Kaffir Bean ...	5·81
Canavalia ensiformis ...	Sword Bean	5·64
Dolichos lablab	Hyacinth Bean	5·49
Mucuna aterrima	Velvet Bean	5·11
Phaseolus aureus	Chinese Bean	4·97
Bauhinia esculenta ...	Gemsbuck Bean	4·73
Phaseolus vulgaris	Kidney Bean	4·65
Phaseolus vulgaris	Haricot Bean	4·64
Phaseolus vulgaris	Boston Bean	4·37
Vicia faba	Broad or Boer Bean ...	3·87
Phaseolus vulgaris	French Bean	3·74
Cicer arietinum	Chick Pea	3·50
Phaseolus lunatus	Lima Bean	3·42
Phaseolus acutifolius ...	Tepary Bean	3·29
Lens esculenta	Lentil	3·19
Phaseolus vulgaris	Sugar Bean	3·07
Voandzeia subterrannea ...	Jugo Bean	2·79

TABLE VI—Destruction of Thiamin During Cooking of Maize.

Maize Product.	State.	Thiamin (mg./2 lb. on *Dry* Basis.	Destruction of Thiamin per cent.
Maize Meal ...	Raw	3·0 ...	—
	"Dry" Pap ...	2·6 ...	13
	Stiff Pap ...	2·1 ...	30
	Pap	1·8 ...	40
Mealie Rice ...	Raw	0·67 ...	—
	Boiled	0·43 ...	36
Samp	Raw	0·73 ...	—
	Boiled	0·52 ...	29
Green Mealies ...	Raw	6·4 ...	—
	Steamed ...	6·0 ...	6
	Boiled	5·8 ...	9

TABLE V—Vitamin Content of Leaves and Pods of Legumes.†

Vitamin Content in mg./100 g. Fresh Material.	Lima Bean Young Leaves.	Groundnut Young Leaves.	Jugo Bean Young Leaves.	Pigeon Pea Very Young Pods.	Cowpea Very Young Pods.	Cowpea Leaves.
Moisture per cent.*	85·5	73·0	74·2	72·3	83·9	81·1
Carotene*	1·12	1·25	2·94	0·14	0·11	1·115
Ascorbic Acid*	62·5	145	185	15	19	61
Thiamin	0·107	0·094	0·173	0·151	0·053	0·022
Riboflavin	—	0 686	0·485	0·942	0·169	0·590
Nicotinic Acid	—	2·32	0·94	1·275	1·14	1·95

† We are indebted to Lieut. Ballin for carrying out the analyses marked with an asterisk.

TABLE VII—B Vitamin Content of Sprouted Seeds.

Seed.	Vitamin Content in μ g./g. on *Dry* Basis.					
	Thiamin.		Riboflavin.		Nicotinic Acid.	
	Unsprouted.	Sprouted.	Unsprouted.	Sprouted.	Unsprouted.	Sprouted.
Maize	3·22	2·17	1·25	1·98	17·9	20·1
Kaffir-corn	3·34	1·73	1·29	2·41	35·1	34·1
Millet (Finger)	1·93	1·56	1·17	2·05	9·5	13·7
Millet (Bulrush)	3·36	2·09	1·55	3·22	23·6	30·2
Sweet Sorghum	2·82	1·44	1·24	1·95	26·2	37·7
Cowpeas	5·43	7·45	1·63	2·81	17·6	25·3

Levy, Weintroub and Fox in 1936 drew attention to the food value, and particularly the antiscorbutic potency of common edible leaves. Here the young leaves and pods of legumes are revealed as good sources of carotene and of the B vitamins as well. The values for riboflavin are particularly striking.

III—The Effects of Cooking.

Cooking of Cereals.—The effect of cooking procedures as applied to cereals and legumes has not as yet been studied by us in any detail. One cannot but wonder at the large number of different ways in which a simple and somewhat uninspiring foodstuff such as maize can be prepared. The preliminary measurements carried out by us appear to indicate that thiamin undergoes least destruction during the cooking of green maize, partly because the period of cooking is shortest. In the case of maize meal losses of thiamin range from 13 to 40 per cent. (Table VI, page 210.) Riboflavin and nicotinic acid do not appear to be seriously affected by cooking.

Potashes.—It is relevant at this stage to introduce the subject of potashes and their effect on vitamin content. The use of potashes is often dictated by necessity in those parts of Africa where salt is scarce or unobtainable. Usually, however, potashes serve to flavour the food and also to soften it during cooking. The large variety of potashes available to the African makes possible the production of a range of sauces and relishes perhaps not inferior to the garnishments prized by the European epicure.

Since we are here concerned with vitamins, the chief factor to be considered is the alkalinity of these plant ashes. Analyses carried out by Dr. Raymond of Zanzibar show a uniformly high content of potassium in various ashes, whether of the salty type used for flavouring or the alkaline type used for softening the leaves and legumes.

Plant ashes may be used in cooking as often as once in two days and the quantity employed is about half the weight of leaves or beans being cooked. In preliminary experiments we have found that the pH produced by the plant ashes is in the neighbourhood of ten. It is not surprising therefore that ascorbic acid is completely destroyed and that losses in thiamin and riboflavin of 100 and of 40 per cent. respectively are encountered. Carotene probably escapes to a large extent unscathed.

It is clear therefore that the use of plant ashes in cooking legumes and leaves serves to neutralise, in part at least, the valuable contribution to vitamin balance which such foods are capable of making. Fortunately there is no evidence of the use of plant ashes in South Africa, probably because salt is so easily available. In Nyasaland however, Barker (1942) found that in a hill village plant ashes were used on about 50 per cent. of the days.

IV.—Germinated and Fermented Foods.

Sprouted Grains and Seeds.—The sprouting of cereal and legume seeds has long been known as a procedure leading to the acquisition of antiscorbutic properties. Our studies of malted cereals from many parts of Africa reveal the fact that malting results in loss of thiamin but in an appreciable increase of riboflavin and often of nicotinic acid (Table VII, page 211). In the last few years a number of papers have appeared reporting the greatly enhanced B vitamin content of germinated beans and peas. While our investigations in this field are in a preliminary stage, one result for legumes is quoted in Table VII to demonstrate this remarkable effect.

Soured and Fermented Foods.—Fermented foods of various kinds constitute a common part of most African diets. Their importance has long been recognised as a means of relieving the monotony of primitive diets. The work of Delf (1921) and of Fox and Stone (1938) has served to establish the anti-scorbutic potency of one fermented food, kaffir-beer. The foods so far investigated by us fall roughly into two groups, depending on whether the fermentation which they have undergone is non-alcoholic or partly alcoholic. In the former category are the "soured" foods such as: *marewu*, thin soured maize meal porridge, *lambalaza*, boiled soured maize meal and similar forms of soured porridge; *leting*, a sour product of maize meal and kaffir-corn malt fermentation; and *amaas*, calabash soured milk.

Kaffir-beer, a thin sweetish-sour gruel with an alcohol content approximately the same as that of ordinary beer, is the chief example of an alcoholic fermented food. Reference will also be made to "small beers" and related products which fall into this group.

The average values for B vitamin content given in Table VIII (page 214), while they do not indicate the considerable variations which occur, convey some idea of the useful contribution to vitamin intake made by these foodstuffs. The fortuitous mixture of simultaneous lactic, acetic and other fermentations which constitutes souring does not greatly affect the vitamin content of cooked cereals. Comparison of *marewa* with the original meal on a dry basis reveals a loss of thiamin of about 30 per cent. (largely due to the preliminary boiling) and increases of riboflavin and nicotinic acid of up to 40 per cent. In the preparation of *lambalaza* the maize meal is first soured and then boiled after the addition of sugar. The loss in thiamin, again mostly due to boiling is close to 50 per cent. but there is a compensating slight increase in riboflavin and nicotinic acid.

The preparation of *leting* and of kaffir-beer involves the souring of a mixture of meal and malt. The meal and the malt differ in different parts of Africa and may be prepared from any of the cereals listed in Table VII. Subsequent straining leads to *leting* which, as can be seen in Table VIII, shows evidence of considerable synthesis of riboflavin and nicotinic acid.

TABLE VIII—B Vitamin Contents of Soured and Fermented Foodstuffs.

Foodstuff.	Solids. Per cent.	Vitamin Content in mg. per pint.			Per cent. Gain or Loss (as compared with ingredients).		
		Thiamin.	Riboflavin.	Niacin.	Thiamin.	Riboflavin.	Niacin.
Marewu	9·0	0·11	0·10	1·39	−30	+32	+38
Lambalaza	14·7	0·18	0·13	2·04	−32	+22	+24
Leting	9·5	0·18	0·20	2·18	+30	+91	+17
Kaffir-beer	8·7	0·28	0·32	2·80	+135	+214	+72
"Second-beer"	5·0	0·13	0·28	1·69	(+155)	(+282)	(+65)
"Third-beer"	3 4	0·14	0·23	0·99	(+291)	(+365)	(+42)
Mkuku	21·7	0·45	0·30	3·66	+15	+71	+51
Amaas	12·1	0·24	1·05	0·90	+ 8	+ 4	−70

TABLE IX.—Comparison of Vitamin Contents of African and European Beverages.

Beverage.	Vitamin Content in mg. per pint.			
	Thiamin.	Riboflavin.	Nicotinic Acid.	Ascorbic Acid.
Beer (Lager)	ca. 0·0	0·42	9·00	0
Tea	ca. 0·0	0·025	ca. 0·0	0
Coffee	ca. 0·0	0·005	ca. 3·0	0
Kaffir-beer	0·28	0·32	2·80	4·8
Marewu	0·11	0·10	1·39	0
Amaas	0·24	1·05	0·90	—

Kaffir-beer.—In making kaffir-beer the soured mash is boiled and cooled; extra malt and water is added whereupon an acidic alcoholic fermentation sets in. Finally the mash is strained, giving the final beer. The values given in Table VIII were obtained with beers prepared from kaffir-corn and maize meals with kaffir-corn malt. The details of the basic process used vary considerably, yet on a dry basis we have found little difference between kaffir beers brewed by Africans, by municipal breweries, and by mine compounds. The yeasts—Saccharomyces and Torulae (Crone, 1941), *Mucor rouxii* (Doidge, 1910) and other microflora whcih play their part in the final alcoholic fermentation, bring about a remarkable synthesis of the three B vitamins which we have measured, and probably of the remainder of the B complex. Thus the final beer is not merely an aqueous-alcoholic extract of the vitamins present in the original meal and malt. On a dry basis it now contains roughly twice as much thiamin and nicotinic acid and three times as much riboflavin as the original ingredients.

"*Small*" *Beers.*—When the beer has undergone its final straining, a considerable residue remains. In the African home it constitutes an inoculum from which, with the aid of more malt, a series of small beers and other fermented foods can be produced. In this way the synthetic activity of the beer culture is prolonged and the ensuing "second" and "third" beers, while lacking the body or flavour of the original beer, are almost equal to it in vitamin content. The watery "third" beer may be consumed as such by women and children; or it may be used to ferment cooked cereals such as steamed maize bread, to which sugar has been added. Through such by-products of the kaffir-beer brew the nutritive benefit derived by the whole African family is greatly extended. Similar fermented foods arise from the *leting* process but we have not as yet secured samples of these products.

Calabash Soured Milk.—Soured milk (amaas) is a food which cannot be discussed in detail here since it brings in an entirely separate topic, that of milk. Suffice it to say that we have found no evidence that during souring synthesis of any vitamin occurs. The possible exception may be ascorbic acid but the difficulty of distinguishing between the true vitamin and other reducing substances has prevented us from reaching any definite conclusion on this point. In the winter milks so far studied the low carotene and vitamin A levels are influenced adversely only by the storage necessary for souring. The low nicotinic acid level present in milk is reduced to one-third.

V.—New Beverages.

It would be appropriate to conclude this section by drawing attention to the manner in which fermented foods tend to balance the inadequacies of cereals such as maize and to act

as a valuable adjunct to them as far as vitamins are concerned. Many aspects cannot be touched upon here, as for example the vitamin-sparing action of high quality protein such as that found in milk.

The extent to which fermented foods are in use should, however, be referred to briefly. The widespread and forceful tea advertising campaign, coupled in urban areas with the prohibition of home-brewing of kaffir-beer, is tending to sound the knell of the traditional fermented foods. In illicit brews speed of preparation is essential and the products can no longer be regarded as foods. Since tea and coffee have become the usual beverages in urban areas it is instructive to compare the published values for lager beer and tea (Drummond and Moran, 1944 and coffee (Teply, Krehl and Elvehjem, 1945) with some of the values for African tribal beverages (Table IX, page 214).

The difference in nutritive value is actually considerably greater than is indicated in Table IX. Other nutrients present in fermented African foods must be taken into consideration. These are absent from tea or coffee except if they happen to be introduced with the water or with milk.

Besides becoming a confirmed tea-drinker, the African in urban and peri-urban areas is making increasing use of sugar and of carbonated beverages of high sugar content. This use of purified carbohydrate itself creates a vitamin lack which cannot be met from the remainder of the diet.

VI.—Discussion.

There are many articles of African diet—wild plants and herbs, fruits and roots which have yet to be studied. However, even the small number of food items discussed in this paper serve to demonstrate the dynamic character of vitamin balance in the African diet. It would seem as if the instinct of food selection, now dormant in, or entirely lost to man, had originally been responsible for the evolution of the primitive African's apparently simple, but in reality richly varied and usually adequately balanced diet.

Natural circumstances can disturb this balance but the equilibrium is eventually restored. When the disturbance is man's conscious or unconscious handiwork, the imbalance is more permanent. Drastic measures, based on factual and scientific knowledge, must then be taken to put matters right. First malnutrition, then deficiency and other diseases are the inevitable consequences which flow from a failure to take such measures.

This paper has dealt with a restricted and perhaps narrow aspect of African nutrition. But it has sought to demonstrate the type of basic fundamental research which is a necessary prerequisite and accompaniment of an intelligent nutritional policy.

VII.—Summary.

A study has been made of two groups of African foodstuffs, namely cereals and legumes. This paper reports the more significant facts which emerge from this study. It also seeks to show how various influences can affect the balance of vitamins in African diets.

The levels of B vitamins provided by the whole grains of African cereals are adequate with respect to thiamin, mostly adequate with respect to nicotinic acid and inadequate with respect to riboflavin. Tribal milling of cereals, consisting of grinding or stamping and subsequent sifting, preserves the greater part of the vitamin content. In response to the demand for refined maize meals, particularly by Africans, European mills remove a substantial proportion of the B vitamin content of the cereal grains. The use of samp and mealie rice constitutes a problem, and the substitution of rice brings about little improvement. A possible solution to this difficulty is suggested.

Legumes play an important part in varying the monotony of primitive African diets. Analysis of dry beans and other legumes has revealed a wide range of thiamin contents, extending to very high levels. Attention is drawn to the valuable nutritional qualities of the young leaves and pods of legumes.

Cooking of cereals destroys a part of the thiamin content. The use of plant ashes of high alkalinity in cooking legumes leads to complete destruction of ascorbic acid and often of thiamin, while riboflavin is also seriously affected.

An appreciable increase in riboflavin and nicotinic acid occurs when grains or seeds are germinated. Thiamin may be reduced or increased. Soured porridges or meal-malt mixtures contain significantly increased amounts of riboflavin and nicotinic acid. Kaffir-beer shows evidence of a remarkable degree of vitamin synthesis during its preparation. The value to the whole African family of "small" beers and other by-products of the kaffir-beer brew is emphasised. Calabash soured milk is shown to contain only one-third of the nicotinic acid present in the original milk.

The subject of new beverages is touched on briefly. Replacement of the traditional tribal beverages by tea or coffee is detrimental to the nutritional status of the African.

Acknowledgements.

It is impossible to refer here in detail to the large number of departments, organisations and individuals who have supplied us with samples for our investigations. The author trusts that he may be permitted to express his appreciation of the kindness of each by thanking all collectively.

The author wishes to pay tribute to the unflagging and stimulating interest displayed by Dr. F. W. Fox in this work. Thanks are also due to Miss S. Sussman, Mr. M. Kropman,

Sgts. Thorp and Goldschmidt and other military personnel who rendered technical assistance at various times by kind permission of the Director of Pathology, South African Medical Corps.

REFERENCES.

Barker, J.: Private Communication (1942).

Barker, J.: *East Afr. Agric. J.*, **8:** 212 (1943).

Crone, W. M.: *J.S. Afr. Chem. Inst.*, **24:** 35 (1941).

Delf, E. M.: *Publ. S. Afr. Inst. Med. Res.*, **2:** 47 (1921).

Doidge, E. M.: *Transv. Dept. Agric., Agric. Sci. Bull.*, No. 5, Pretoria Government Printer ((1910).

Drummond, J. C. and Moran, T.: *Nature*, **153:** 99 (1944).

Fox, F. W. and Stone, W.: *S. Afr. J. Med. Sci.*, **3:** (1938).

Golberg, L., Thorp, J. M. and Sussman, S.: *S. Afr. J. Med. Sci.*, **10:** 87 (1945).

Levy, L. F.: Weintroub, D. and Fox, F. W.: *S. Afr. Med. J.*, **10:** 699 (1936).

Teply, L. J., Krehl, W. A. and Elvehjem, C. A.: *Arch. Biochem.*, **6:** 139 (1945).

South African Journal of Science, *Vol. XLII, pp. 219-223, June, 1946.*

THE CONSTRUCTION OF A HELIOSTAT FOR USE IN MICROSCOPY

BY

Dr. A. G. Oettlé with the technical assistance of J. G. Bryden, *Department of Anatomy, University of the Witwatersrand, Johannesburg.*

Read 2nd July, 1945.

Direct sunlight has been the light of choice in many types of microscopy, although nowadays, for reasons of convenience, artificial lamps have almost entirely replaced it. The use of sunlight has always involved some inconvenience, greatest in the time of Lieberkuhn (1739) whose microscope had to be equipped with a ball and socket joint in order to direct it against the sun. Hooke had introduced the substage mirror in 1668 (Gage, 1943) but the idea had not spread. and in 1743 John Cuff wrote to claim the honour of being " the fortunate person who . . . began to consider that plain Looking Glass could Reflect the Sun's Rays through the Tube placed Horizontally, at any Time of the Day."

The first apparatus to compensate the apparent movement of the sun had already been devised (1742) by s'Gravesande, and the older works on microscopy contain many references to the heliostat which was used for the most critical work. Modern microscopists, however, with a notable exception in Professor Pijper (1931-1932, 1938) have dismissed sunlight as too fickle and have used artificial sources which are reliable, though inferior.

For some time I have been engaged in studies on human spermatozoa, chiefly under the dark field. After a demonstration by Professor Pijper of the use of the heliostat for this work, it was decided to construct such an instrument, as a factory-made product was unobtainable at the time and would have been expensive at any time. Although Strong (1943) gives a working diagram for a heliostat, the literature available to us on the construction of this instrument proved inadequate. It has been thought worth while, therefore, to describe the principles involved and the method of construction adopted, as this means of illumination appears to be specially useful under South African conditions.

Advantages of Sunlight.

Direct sunlight has an energy distribution approximating that of a black body at 5400°K, and provides parallel rays of

intense white light of relatively little heat. Laboratory sources have considerably lower temperatures and so give a greater proportion of the longer rays, producing a hot and yellow light that may be tiring to use. The figures given for the comparative brightness of the sun vary (920-1600 candles per sq. mm.) (Hodgman, 1939, Strong, 1943) but they far exceed those for the ordinary carbon arc (130 candles per sq. mm.) Extreme temperatures (7600°K) have been obtained in the carbon arc operated at 22 atmospheres in an inert gas, producing brightnesses attaining to 2,800 candles per sq. mm. (Strong, 1943) but these lamps have not been used in microscopy.

Sunlight has the disadvantages of inconstancy and varying intensity. In addition the apparatus needed to receive it makes some architectural demands. Yet South Africans are specially favoured, and what may be sound objections to its use in London with an average of 3·8 hours of sunlight per day, may not hold in Johannesburg with a mean daily sunshine of 8·7 hours (Riemerschmidt, 1940). Here the winter sun is remarkably constant, but the summer sunshine is frequently interrupted by small clouds. In spite of this, the advantages of sunlight make it worth waiting for in many instances.

Principle of the Heliostat.

There are many types of heliostat, ranging from that turned by hand to the one guided by photoelectric cells and driven by electric motors. Simpler models are operated by clockwork and two types which are easy to make will be described.

In the first type, Fahrenheit's heliostat, the mirror is held in an equatorial axis and rotates on a polar axis at the same angular velocity as the sun, viz., once in 24 hours from east to west. The mirror is set in the same right ascension as the sun, and tilted to reflect in the axis of rotation, i.e., towards the celestial pole. Consequently the reflected ray rotates on itself but is not displaced. The mirror should be adjusted for changes in the sun's declination, since the normal to its reflecting surface must bisect the polar distance. The mirrors needed for redirecting the light may be fixed.

The second class of instrument is the coelostat; it is easier to make and is that described below. The mirror rotates as in the previous type, from east to west on an axis parallel to the earth's, but at half the speed, i.e., once in 48 hours. The mirror is fixed with its reflecting surface in the axis of rotation. The varying declination of the sun will change the position of the arc in which the reflected ray lies, and in addition the intensity of the reflected ray will vary with the angle of incidence which may change considerably. Corrections for changes in the sun's declination are made by the second mirror or by raising or lowering the heliostat. (Pijper, 1931-1932).

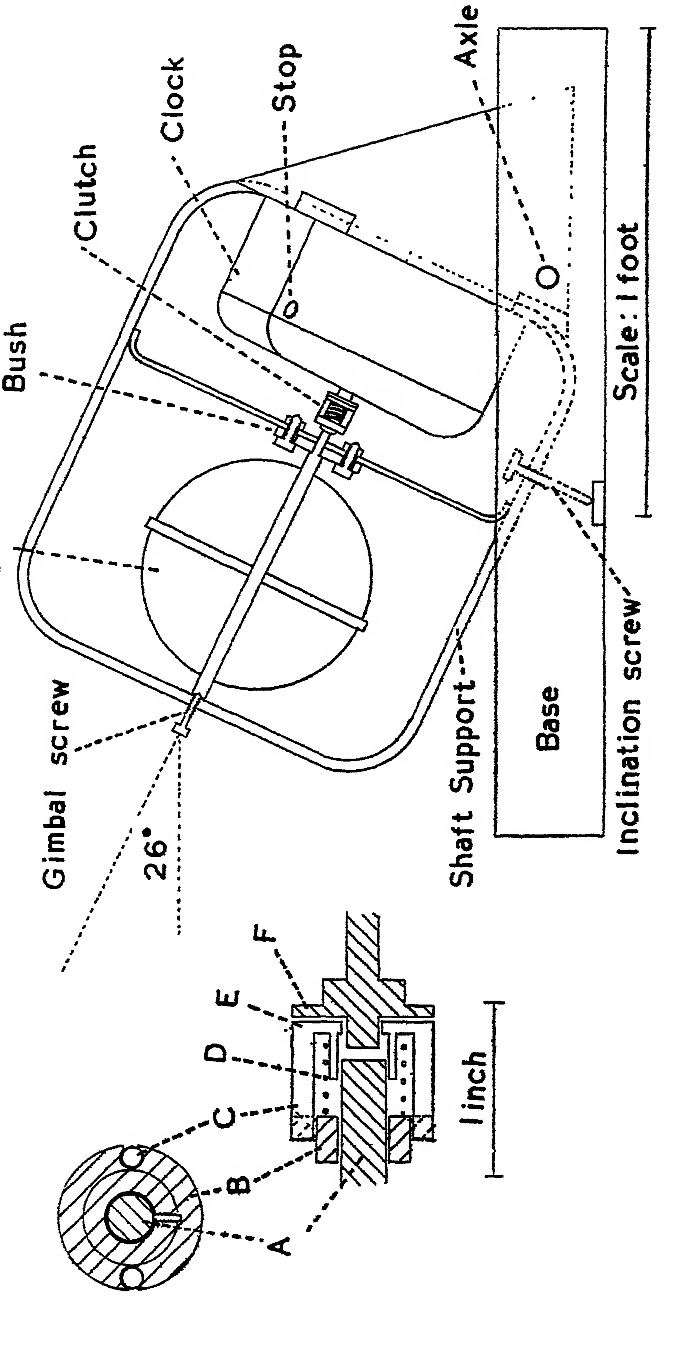

Axle
Stop
Clock
Clutch
Bush
Mirror
Gimbal screw
26°
Shaft Support
Base
Inclination screw
Scale: 1 foot
A
B
C
D
E
F
1 inch

FIG. 1

FIG. 2

Construction.

The base is a rectangular frame 20 x 10 inches made of wood $2\frac{1}{2}$ x $1\frac{1}{4}$ inches. A pivoted support is fixed at one end of the base (Fig. 1), and the clock is screwed to this. Tilting at this axle enables changes to be made in the axis of rotation. A powerful clock was needed as the mirror is not counterbalanced and a 30-day Swiss Movement Clock, was found to be suitable. This clock is a type used for regulating street lighting and the hour hand turns once in 24 hours. For convenience, a stop is attached in which a fine copper spring engages the flywheel, and starts it again automatically when the stop is released. A train of gear wheels is inserted to halve the speed of the drive, which engages the axle bearing the mirror by a friction clutch to allow for adjustments when setting. Several types of clutch were tried, from a cork fitting into a drum to the one illustrated (Fig. 2), and there seems no doubt that the spring clutch is necessary. It consists of two friction places (E and F), the upper having two shafts (C) which engage with slots in a dog (B). The dog is held on the mirror axle (A) by a grub-screw. Pressure is supplied by a spring (D) wound from steel wire and placed between the dog and the upper friction place.

A rectanguar framework of steel $\frac{5}{8}$ x $\frac{1}{8}$ inch is attached to the clock (Fig. 1) and forms the shaft support which holds the mirror axle at an angle of approximately 26° to the horizon. Final adjustments are made by the inclination screw in the shaft support, to obtain the exact angle of 26°, which is the latitude of Johannesburg. The mirror axle is held by a bush and gimbal screw. The bush is attached to the shaft support by bolts which pass through slotted holes to allow for minor adjustments in the bush. The mirror is a 6-inch circle of back silvered plate glass, and is held to the axle and its cross bar by screws which overlap its edges.

The north-south meridian is found by the shadow pole method described by Hogben (1943, p. 50) by bisecting the angle made by morning and afternoon shadows of equal length. The heliostat is set with the mirror axis parallel to this line, and consequently parallel to the axis of the earth.

Possible Improvements.

There are several changes which would be for the better, but have not been found to be necessary as yet. A counterbalanced mirror would relieve the clock of the load which makes it lose time. In the present instrument the shaft support is vertical, and so throws a shadow on the mirror at midday. This might have been avoided by a horizontal frame with some other arrangement for the inclination screw. Levelling screws would eliminate errors due to an uneven surface of the ground. Furthermore, there is a considerable loss of light in the several reflections involved, for the reflection coefficient of a second

surface mirror is given as 0·88-0·93, i.e., a loss of about 10 per cent. (Hodgman, 1943, p. 1807). As the light has three reflections and must also pass a window pane, before reaching my condenser, about one-third will be lost, without allowing for dust on the surfaces. These losses could be greatly reduced by the use of a front silvered mirror and reflecting directly on to the condenser. In spite of these imperfections the heliostat has been quite adequate for microcinematography in dark field.

Acknowledgments.

I wish to thank Professor Pijper for his advice and for a demonstration of his results. Mr. E. Williams provided the clock and Mr. J. G. Bryden made the instrument in the Anatomy Department workshop and I take this opportunity of thanking them.

BIBLIOGRAPHY.

CUFF, JOHN. 1743: quoted by Nelson, E. M. *J. R. Micr. Soc.* 427-439 (1910).

GAGE, S. H.: The Microscope, 17th ed. Comstock Publishing Co., Inc., N.Y. (1943).

'sGRAVESANDE: "Physices Elementa." quoted in The New International Encyclopaedia, Vol. XI, 2nd ed. Dodd Mead & Co., New York (1925).

HOGBEN, L.: Mathematics for the Million. George Allen and Unwin, London (1943).

HODGMAN, C. D.: Handbook of Chemistry and Physics, 23rd ed., Chemical Rubber Publishing Co., Cleveland, Ohio (1939).

PIJPER, A.: *Zbl. Bakt. I. Abt. Orig.* **123:** 195-201 (1931-1932).

PIJPER, A.: *J. Path. Bact.*, **47:** 1-17 (1938).

PLUMMER, F. E.: *This Journal*, **35:** 454-460 (1938).

RIEMERSCHMIDT, G.: *Onderstepoort J. Vet. Sci.* **15:** 343-430 (1940).

SHILLABER, C. P.: Photomicrography in Theory and Practice, John Wiley and Sons, Inc. New York (1944).

STRONG, J.: Modern Physical Laboratory Practice, Blackie & Son, London and Glasgow (1943).

South African Journal of Science, *Vol. XLII, pp. 224-235, June, 1946.*

THE POWER COLLECTION OF MAMMALIAN REMAINS FROM THE VAAL RIVER DEPOSITS AT PNIEL

BY

H. B. S. Cooke,

Department of Geology, University of the Witwatersrand.

AND

Dr. L. H. Wells,

Department of Anatomy, University of the Witwatersrand.

With 1 Text Figure.

Read 2nd July, 1945.

Introduction.

In a short paper read before this Association six years ago, one of us (Cooke 1939) described a small collection of mammalian fossils from the Vaal River gravels at Pniel, near Barkly West, C.P., presented to the museum of the Archaeological Survey at Johannesburg by Mr. J. H. Power of Kimberley. Mr. Power has since obtained further material from Pniel, which has been examined by us partly in collaboration and partly independently.

In the 1939 paper it was remarked that to the best of the writer's knowledge no faunal assemblage from particular horizons of the Vaal gravels had as yet been described. The periodic description by various authors of individual extinct species from these gravels has led to the general impression that the fauna was dominated by extinct forms, and it was hoped that the description of a faunal assemblage, however small, might give a better perspective of the fauna as a whole. Now, however, the collection made by Mr. Power has been increased fourfold by additional material, and affords us a more comprehensive view of this fauna than has previously been possible. At the same time subsequent work has improved our knowledge, and has shown the need for emending some of the identifications suggested in the 1939 paper more particularly with respect to the antelopes. It is therefore considered that an account of the entire collection as it now stands will give a better picture than one limited to the new material alone, although with few exceptions these later additions form the more important part of the whole.

Description of Material.

Order Proboscidea—Family Elephantidae.

Archidiskodon cf. *broomi* Osborn.

One moderate-sized piece of an elephant molar presents about one-third of the breadth of three plates, and there are also three broken pieces of single plates which appear to be closely similar to those of the large fragment. The broken molar shows marked outward radiation of the plates towards the grinding surface and is almost certainly the hinder portion of an upper tooth. At the grinding surface the three plates occupy 69 mm.; the anterior plate is 87 mm. high as preserved, the base being somewhat damaged. Each plate is about 15 mm. wide, is anteriorly concave and has strongly crimped enamel; at the grinding surface the plates are separated by a nearly equal width of cement. The general features of this tooth indicate an Archidiskodont character, and as far as identification of such poor material is possible it suggests *A. broomi*, of which the type specimen also came from Pniel (Osborn 1928).

In addition to the above material, four fragmentary portions of individual plates are not identifiable but may belong to an Archidiskodont.

Palaeoloxodon sp.

In the 1939 paper three posterior plates forming part of a lower molar were described as "*Archidiskodon* sp." and their measurements were given. This specimen is now considered to belong to one of the more hypsodont species which Osborn (1934) includes in the genus Palaeoloxodon. In many respects it is comparable with the lower molar of *P. darti* Cooke from the Victoria Falls (Cooke and Clarke 1939), the only large South African Palaeoloxodont in which this tooth is known. It might, however, be a lower tooth of *P. transvaalensis* (Dart), although the curvature of the plates is convex anteriorly in the type upper molar of that species, and faintly concave anteriorly in the foremost plate of the Pniel tooth. Nevertheless it is evident that this fragment belongs at least to a related species.

The worn fragment of a median plate, described as "indeterminable" in the 1939 paper, is perhaps more suggestive of Palaeoloxodon than of Archidiskodon.

Order Perissodactyla—Family Equidae.

Equus poweri Cooke.

The type right upper first molar of this species was described and figured in the 1939 paper, together with a doubtfully referred left upper third molar. No new material referable to *E. poweri* has been added to the Power collection. It may however be mentioned that a much less worn left upper first molar, found at Windsorton, agrees remarkably well with the type and confirms the distinctness of this species.

Equus capensis Broom.

In the 1939 paper two lower premolars and a lower molar were figured as *E. capensis*, but as a result of renewed study one of the premolars is now referred to *E. harrisi* (*vide infra*). The remaining premolar and the molar, together with two premolars since collected, have crown breadths of 18-20 mm. and unquestionably belong to *E. capensis;* one of the premolars is illustrated as Fig. I, A.

Five upper cheek teeth whose breadth exceeds 30 mm. are attributed to *E. capensis;* they comprise a left second premolar and a right and left first molar moderately worn, and two extremely worn teeth of uncertain position. The outer half of a left third premolar and the anterior extremity of a right second molar, both in early wear, also definitely belong here. In addition, an incomplete left third molar has been provisionally ascribed to *E. capensis,* although its breadth (29 mm.) is somewhat less than is usual in this species.

In the 1939 paper two imperfect upper teeth were doubtfully referred to *E. cawoodi* Broom, but it was remarked that they were smaller than the type and had affinities also with *E. kuhni* Broom. Cooke (1940) has advanced reasons for believing that the type of *E. cawoodi* represents merely a complex early stage of wear in the upper dentition of *E. capensis*. These two imperfect teeth are considered to be below the limiting range of size in *E. capensis* and must be placed in other species.

Equus harrisi Broom.

As previously mentioned, a right lower fourth (?) premolar, referred in the 1939 paper to *E. capensis*, is now assigned to *E. harrisi*. This tooth is refigured here (Fig. I.B.), and it will be seen to differ from that of *E. capensis* in its slightly smaller size (breadth 17 mm.) and in the details of the enamel patern. In these respects it agrees closely with the type teeth of *E. harrisi* (Broom 1928).

Two other lower teeth are tentatively referred to this species. One of these is a left fourth premolar in very early wear, whose maximum enamel breadth (below the crown) is 17 mm. In its present state of wear this tooth shows an enamel pattern almost identical with that of the fourth premolar in the type dentition of *E. plicatus* (van Hoepen), but such a resemblance at this stage of wear is of no diagnostic significance. The other tooth is a left second molar in full, but still relatively early wear, with a breadth of 16 mm.

Equus cf. *kuhni* Broom.

Three upper teeth are provisionally assigned to this species although none of them is in a condition permitting certain identification. One of them is a left second molar with a breadth of 29 mm.; its crown is largely obscured by a ferruginous incrusta

tion, but the visible features of the enamel pattern agree excellently with those of *E. kuhni*. An erupting right premolar also has a breadth of 29 mm. below the crown. The remaining tooth is a right third molar in very early wear, whose breadth below the crown is 27 mm. In addition, a fragmentary unworn tooth mentioned in the 1939 paper as "*E. cawoodi*" is better identified as *E.* cf. *kuhni*.

Equus cf. *sandwithi* Haughton.

Three lower teeth show the markedly oblique anterior face characteristic of this species: a right second molar in early wear, 15.5 mm. broad below the crown; a right fourth premolar lacking its hinder portion, 16 mm. broad; and an incomplete right third molar, 14 mm. broad anteriorly. A newly erupted right upper premolar in a very rolled state may also be assigned provisionally to *E. sandwithi;* it has a very short bilobate protocone, but differs in a number of features from the type of *E. poweri*.

Equus burchellii (Gray).

The criteria by which the teeth of Burchell's zebra can be distinguished from those of the true quagga have been restated by Cooke (1943). According to these, a right lower fourth premolar in early wear and a right and left lower second molar unquestionably belong to *E. burchellii*, and an incomplete left lower third molar may also be assigned to this species. Three upper third molars, two left and one right, also appear to belong to Burchell's zebra, although the third molar of this form is very difficult to distinguish from that of a quagga.

Equus cf. *quagga* Gmelin.

An unworn right upper fourth (?) premolar and an extremely worn right upper third molar, which are within the size range of the recent species, show features which approximate them rather to the true quagga than to Burchell's zebra. Among the teeth assigned to *E. burchellii* in the 1939 paper, a left third upper molar in early wear may also belong in reality to the quagga, as may the more complete of the broken teeth previously labelled *E.* cf. *cawoodi*.

Order Artiodactyla—Family Bovidae.

Taurotragus oryx (Pallas).

The outer half of a right lower second (?) molar definitely belongs to the eland. In the 1939 paper five unworn teeth were doubtfully referred to "a large antelope resembling Taurotragus," but it was added that "it is doubtful if they actually fall within that genus." Further study has shown that none of them does so, and in this paper they are referred to other genera.

Damaliscus cf. *albifrons* (Burchell).

A left mandibular fragment with the three lower molars,

embedded in a ferruginous sandy nodule, is indistinguishable from that of the existing blesbok. Portions of a right and a left third lower molar and a left third upper molar, all in early wear, together with a moderately worn left second lower molar and a broken right upper third molar, seem also to belong to this antelope. The lower second molar was asigned in the 1939 paper to "*Kobus* aff. *ellipsiprymnus*," but it now appears that the waterbuck is not, in fact, represented in this collection.

cf. *Connochaetes* sp.

Two right lower second molars and a right lower fourth premolar, together with a left and a right upper second molar and a right upper third molar, may belong to this genus. They cannot, however, be identified specifically, as the dental characteristics of the different living and extinct species have not been satisfactorily determined.

cf. *Alcelaphus caama* (Cuvier).

A damaged right upper first molar and left upper second molar, and an erupting left lower third molar, more closely resemble those of the hartebeest than those of the wildebeest. The teeth of these genera, however, resemble each other so closely that as yet no certain means has been devised for distinguishing between them. It nevertheless seems probable that both are represented in this collection.

cf. *Peloroceras helmei* (Lyle).

Two complete and three fragmentary lower molars are Alcelaphine in form, but in size greatly exceed those of either hartebeest or wildebeest. Teeth resembling these in size and form have been tentatively referred by Cooke (1940) to the extinct giant hartebeest-like antelope *Peloroceras helmei*, described from horncores by Lyle (Dreyer and Lyle 1931) and van Hoepen (1932). Upper molars of corresponding character have been described by Wells and Cooke (1942). In this collection a broken right first (?) molar and a fragment of another tooth appear to belong to the same type.

An erupting right upper third molar also proves on sectioning to be Alcelaphine in character (Fig. I. C), but appreciably larger than that of any living wildebeest or hartebeest, its length being 32 mm. as against a maximum of 27 mm. for these antelopes. It is however smaller than third molars from Florisbad referred to Peloroceras, which range from 36 mm. to 39 mm. in length (Fig. I, D), and therefore may possibly belong to some other extinct Alcelaphine species, such as "*Bubalis*" *priscus* Broom (1909).

Sylvicapra grimmia (Linn).

A right mandibular fragment with the three lower molars, and also a broken left lower third molar, cannot be distinguished from those of the existing Cape duiker.

cf. *Aepyceros melampus* (Lichtenstein).

Two left mandibular fragments, one with the three molars in advanced wear, the other with the second molar in early wear and the third molar erupting, together with a moderately worn left lower third molar, agree most nearly with the existing impala. The worn teeth resemble in form those of the springbok, but are considerably smaller, while the relative size of the the third molar is quite different from the proportion encountered in the duiker. Wells and Cooke (1942) described teeth from Vlakkraal, near Florisbad, intermediate in character between those of impala and duiker, which were suspected of representing an extinct species. The specimens from Pniel are similar to these, but the material is insufficient to establish the presence of a new species, and it appears best to refer these remains tentatively to an impala.

Family Hippopotamidae.

Hippopotamus amphibius Linn.

The hippopotamus is represented by more than twenty fragments, including incisors, canines and cheek teeth. As was pointed out in the 1939 paper, certain of these teeth are extremely fossilised, and have very probably been derived from older deposits. There are no grounds, however, for referring any of the remains to a species different from *H. amphibius*.

Family Suidae.

Phacochoerus aethiopicus (Pallas).

Shaw (1939) has confirmed the opinion of van Hoepen and van Hoepen (1932) that among recent South African wart-hogs two species, *P. aethiopicus* (Pallas) and *P. africanus* (Gmelin) can be distinguished on the basis of root formation in the third molars. Roots develop upon the anterior columns of *P. africanus* before attrition of the posterior columns has commenced, whereas in *P. aethiopicus* closure of roots only occurs considerably later, after all the columns have been abraded.

In this collection a left lower third molar shows no signs of root formation, although the posterior columns are in full wear. It falls well within the normal range of variation in size of existing wart-hogs, and may confidently be assigned to *P. aethiopicus*.

Phacochoerus africanus (Gmelin).

A well preserved right upper third molar has only slightly worn posterior columns, its height at the posterior end being 58 mm., but it shows a well-developed anterior root. It appears to be well within the range of *P. africanus*.

Two fragments, the anterior part of an erupting lower third molar and the middle portion of a mature right lower third molar, could belong to either of these species.

Phacochoerus cf. *compactus* (van Hoepen and van Hoepen).

A right lower third molar which lacks its hinder portion, has no differentiated anterior roots although considerably worn. It thus belongs to the *aethiopicus* group, but is appreciably larger and has a more complex enamel pattern than is usual in *P. aethiopicus*. The occlusal breadth of this tooth is 14 mm., and its occlusal length must have been 55—60 mm. As Fig. I, E. shows, the marginal columns have very strongly developed inwardly projecting lobes, which in the anterior part of the tooth meet in the mid-line, interrupting the series of median columns, and which tend to unite with the median columns to produce complex figures.

The enamel pattern of this tooth approaches closely to that of the type lower molar of *Synaptochoerus hieroglyphicus* van Hoepen and van Hoepen (1932), although the specimen appears to be somewhat narrower. Van Hoepen and van Hoepen seem to have suspected that *S. hieroglyphicus* might represent the lower dentition of their *Stylochoerus compactus*. Shaw (1939) claimed that both *Stylochoerus compactus* and *Synaptochoerus hieroglyphicus* fall within the normal range of variation of Phacochoerus, and that the teeth described by van Hoepen and van Hoepen probably belong to one of the recent wart-hogs. Wells and Cooke (1942) concluded, however, that "*Stylochoerus*" *compactus* may be regarded as a distinct species within the genus Phacochoerus, related to *P. aethiopicus* by its lack of early differentiated roots, but distinguished by its greater size and a tendency towards a more complex enamel pattern. Leakey (1942) maintains that wart-hogs whose teeth display flattened marginal columns with well-defined internal or antero-internal lobes should be separated generically from Phacochoerus. In our material, however, the transition from the sub-cylindrical to the flattened and lobulated form of marginal column is so gradual that we do not consider it possible to draw a line of generic distinction.

The essential characters which this tooth shares with the type of "*Synaptochoerus*" *hieroglyphicus* appear to be of specific though not of generic value. These same features, however, might very well be expected in the lower molars of "*Stylochoerus*" *compactus*, and it is in fact probable that *hieroglyphicus* represents the lower dentition of *compactus*. This specimen has therefore been identified as *Phacochoerus* cf. *compactus* (van Hoepen and van Hoepen), rather than as *P. hieroglyphicus* (van Hoepen and van Hoepen).

Phacochoerus altidens Shaw and Cooke.

A portion of a wart-hog upper (?) third molar belongs to a type even larger than *P. compactus*. The full width of this tooth is preserved only at its posterior end, where it measures 13 mm., but more anteriorly it must have attained a breadth of at least 16 mm. Although the general arrangement of the columns agrees with that seen in *P. compactus*, they are considerably larger.

As Fig. I, F, shows, the marginal columns are very elongated, with strongly developed antero-internal lobes, and in the middle portion of the tooth there is a double row of elongated median columns. This fragment corresponds almost exactly with the very large tooth descrbied by Shaw and Cooke (1941) as *P. altidens*.

Leakey (1942) has suggested that *P. altidens* may belong to his genus Afrochoerus. The main ground for such an ascription, and indeed for the creation of this genus, is the presence of very elongated " Y-shaped " marginal columns. It has been pointed out above that this is not a satisfactory criterion of distinction from Phacochoerus, and the validity of Leakey's genus is therefore doubtful. If the genus Stylochoerus of van Hoepen and van Hoepen should be validated by future investigation, *P. altidens* would probably be included in it, but in the mean time this species may justifiably be retained in Phacochoerus.

Discussion.

In this collection, which now includes more than a hundred specimens, twenty-one types have been provisionally identified, including Proboscidae, Perissodactyla (Equidae), and Artiodactyla (Bovidae, Hippopotamidae and Suidae). Some are only generically identifiable, but the remainder have been referred to species already known, either living or extinct. Further study may show some of these to be synonyms, but on the other hand it has been indicated that additional species may in fact be represented.

The extinct giant hartebeest-like antelope, provisionally identified as *Peloroceras helmei*, has not hitherto been listed in the fauna of the Vaal deposits, although it has almost certainly been included in previous collections. It seems highly probable that the teeth assigned by Fraas (1907) to " *Damaliscus* sp." belong in reality to this large extinct form. If this is the case, the identification of " *Damaliscus* cf. *albifrons* in the Power collection is an addition to the fauna. Other species not hitherto identified with certainty in these deposits are *Taurotragus oryx*, *Sylvicapra grimmia*, *Phacochoerus africanus* and the forms compared with *Equus quagga*, *Alcelaphus caama*, *Aepyceros melampus*, and *Phacochoerus compactus*. All these except the last are recent species.

Definitely extinct species represented in this collection include elephants, the larger equines, at least one antelope (cf. *Peloroceras helmei*), and apparently two large wart-hogs (*Phacochoerus compactus* and *P. altidens*.). Those which unquestionably survive to recent times are the small zebras, several antelopes (eland and duiker certainly, blesbok and hartebeest probably), the hippopotamus, and the wart-hogs *Phacochoerus aethiopicus* and *P. africanus;* whether the wildebeest and the supposed impala are extinct or living species is uncertain. The recent species thus make up approximately half of this assemblage. There are, of course, other extinct species recorded from the

Vaal which are not represented in the Power collection. However, future additions to our knowledge of the Vaal fauna will probably increase the proportion of recent rather than of extinct species.

These fossils have been recovered from the spoil--heaps of diamond-diggers operating in the " Younger Gravels " of the Vaal (Sohnge, Visser and van Riet Lowe, 1937). The fossilisation of all the remains is practically complete, and some of them are partially encrusted with ferruginous material. It is considered that they belong either to the gravels or to the immediately overlying sands, although some may possibly be secondarily derived from earlier deposits.

Söhnge, Visser and van Riet Lowe (1937) in describing the Pniel Estates area state:

> " Towards the river the gravel is exceptionally coarse, and the constituents, held in calc-tufa, are frequently over three feet in diameter. Away from the river the deposit thins out gradually against the slope of diabase leading up to Pniel Koppie. The sandy overburden, 12 to 20 feet thick, is highly oxidised; even the top-most part of the gravel may locally be deep red in colour."

In the figure which accompanies this description the gravels are described simply as " Younger Gravels " and the sands are shown as " Sand III " of the " First Wet Phase." Professor van Riet Lowe informs us that no implements have been recovered from the sands, but he confirms that their physical appearance is quite characteristic of " Sands III." There is, however, some doubt about the particular age of the gravels and it is possible that they were originally " Younger Gravels II " somewhat reworked before the deposition of the sand. The sands may themselves have been reworked to a limited extent.

As far as the fossil specimens themselves are concerned, the dating evidence they provide is not conclusive. A large number are abraded and show signs of rolling, and it is highly probable that they come from the gravels. Some elephant remains and a hippo incisor are very rolled and are also most heavily mineralised, so that they may well be secondarily derived from an earlier deposit. The specimens showing adherent ferruginous sand grains are possibly from the sands overlying the gravels, but such *species* as these represent are usually included amongst the rolled and abraded material as well. With the exception of the elephant teeth and the hippo incisor all the material is more or less uniformly mineralised and polished, so that there appears to be no reason for supposing that two distinct phases are represented. While it is possible that some of the living species may post-date the " Younger Gravels " phase of deposition, it appears most probable that the bulk of this material forms a fairly coherent whole, representative of the fauna of the later part of the " First Wet Phase." This is contemporary with the upper divisions of

the Stellenbosch Culture of the Vaal, and may be regarded as broadly Middle Pleistocene (Cooke 1941). The Ungulate fauna of the Younger Gravels appears, therefore, to have included a fair proportion of living forms as well as a number of extinct species.

This Mid-Pleistocene fauna has been transformed into that of recent times through the disappearance of a number of species, especially those of larger size. Although these may have been to some extent replaced by immigrant forms, the modern fauna as a whole is impoverished compared with that of the Middle Pleistocene. The upper Pleistocene fauna of the Middle Stone Age, represented for example at Vlakkraal (Wells and Cooke 1942), shows an intermediate stage in this process, in which a minority of these extinct species still persisted.

SUMMARY.

Remains collected by Mr. J. H. Power from the Middle Pleistocene " Younger Gravels group of deposits " of the Vaal River at Pniel near Barkly West, Cape Province, have been identified as follows (forms extinct before historical times are marked †):

Proboscidea: †*Archidiskodon* cf. *broomi* Osborn, †*Palaeoloxodon* sp.; Perissodactyla (Equidae): †*Equus poweri* Cooke, †*E. capensis* Broom, †*E. harrisi* Broom, †*E.* cf. *kuhni* Broom, †*E.* cf. *sandwithi* Haughton, *E. burchellii* (Gray), *E.* cf. *quagga* Gmelin Artiodactyla (Bovidae): *Taurotragus oryx* (Pallas), *Damaliscus* cf. *albifrons* (Burchell), cf. *Connochaetes* sp., cf. *Alcelaphus caama* (Cuvier), †cf. *Peloroceras helmei* (Lyle), *Sylvicapra grimmia* (Linn.), cf. *Aepyceros melampus* (Lichtenstein); (Hippopotamidae): *Hippopotamus amphibius* Linn.; (Suidae): *Phacochoerus aethiopicus* (Pallas), *P. africanus* (Gmelin), †*P.* cf. *compactus* (van Hoepen and van Hoepen), †*P. altidens* Shaw and Cooke. Several of these types, both recent and extinct, have not previously been recorded from these deposits. It is concluded that the Middle Pleistocene fauna included a considerable proportion of recent ungulates, but that the recent fauna had been impoverished before historic times by the loss of a number of forms chiefly of large size.

In conclusion we wish to thank Professor C. van Riet Lowe, Director of the Archaeological Survey of the Union of South Africa, for the opportunity of studying this most valuable collection.

REFERENCES.

Broom, R.: "On a Large Extinct Species of Bubalis." *Ann. S. Afr. Mus.* **7**: 279-280 (1909).

Broom, R.: "On Some New Mammals from the Diamond Gravels of the Kimberley District." *Ann. S. Afr. Mus.* **22**: 439-444 (1928).

Cooke, H. B. S.: "On a Collection of Fossil Mammalian Remains from the Vaal River Gravels at Pniel." *This Journal*, **36**: 412-416 (1939).

COOKE, H. B. S.: "A Preliminary Account of the Wonderwerk Cave, Kuruman District." Section II: "The Fossil Remains." *This Journal*, **37**: 300-312 (1940).

COOKE, H. B. S.: "A Preliminary Survey of the Quaternary Period in Southern Africa." *Arch. Ser. IV, Bureau of Archaeology.* Pretoria: Govt. Printer. 60 pp. (1941).

COOKE, H. B. S.: "Cranial and Dental Characters of the Recent South African Equidae." *This Journal*, **40**: 254-257 (1943).

COOKE, H. B. S. and CLARK, J. D.: "New Fossil Elephant Remains from the Victoria Falls, Northern Rhodesia, and a Preliminary Note on the Geology and Archaeology of the Deposit." *Trans. Roy. Soc. S. Afr.* **27**: 287-319 (1939).

FRAAS, E.: „Pleistocäne Fauna aus den Diamantenseifen von Sud-Afrika." *Zeit. d. Deutsch. geol. Gesell.*, **59**: 232-243 (1907).

DREYER, T. F. and LYLE, A.: "New Fossil Mammals and Man from South Africa." Bloemfontein: Grey Univ. College. 60 pp. (1931).

LEAKEY, L. S. B.: "Fossil Suidae from Oldoway." *Journ. E. Afr. Nat. Hist. Soc.* **16**: 178-179 (1942).

OSBORN, H. F.: "Mammoths and Man in the Transvaal." *Nature*, **121**: 672-673 (1928).

OSBORN, H. F.: "Primitive Archidiskodon and Palaeoloxodon of South Africa." *Amer. Mus. Novitates*, No. 741, 15 pp. (1934).

SHAW, J. C. M.: "Growth Changes and Variations in Wart-Hog Third Molars and the Palaeontological Importance." *Trans. Roy. Soc. S. Afr.*, **27**: 51-94 (1939).

SHAW, J. C. M. and COOKE, H. B. S.: "New Fossil Pig Remains from the Vaal River Gravels." *Trans. Roy. Soc. S. Afr.* **28**: 293-299 (1941).

SOHNGE, P. G., VISSER, D. J. L. and VAN RIET LOWE, C.: "Geology and Archaeology of the Vaal River Basin." *Memoir No. 35, Geol. Survey of the Union of S. Afr.* Pretoria: Govt. Printer. 164 pp. (1937).

VAN HOEPEN, E. C. N.: „Voorlopige Beskrywing van Vrystaatse Soogdiere. *Pal. Nav. Nas. Mus. Bloemfontein.* **2**: (5) (1932).

VAN HOEPEN, E. C. N. and VAN HOEPEN, H. E.: „Vrystaatse Wilde Varke." *Pal. Nav. Nas. Mus. Bloemfontein*, **2**: 39-62 (1932).

WELLS, L. H. and COOKE, H. B. S.: "The Associated Fauna and Culture of the Vlakkraal Thermal Springs, O.F.S. III. The Faunal Remains," *Trans. Roy. Soc. S. Afr.* **29**: 214-233 (1942).

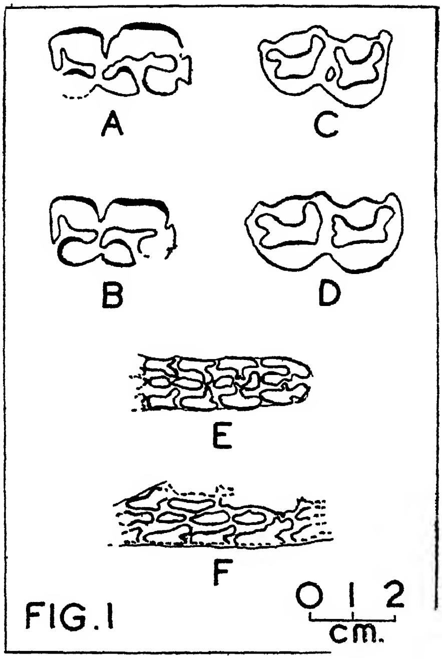


FIG. I: A. Enamel pattern of right lower fourth premolar, *Equus capensis* Broom; B. Enamel pattern of right lower fourth (?) premolar, *Equus harrisi* Broom; C. Enamel pattern (on sectioning) of large Alcelaphine right upper third molar; D. Enamel pattern of right upper molar from Florisbad, referred to *Peloroceras helmei* (*Lyle*); E. Enamel pattern of right lower third molar, *Phacochoerus* cf. *compactus* Van Hoepen and Van Hoepen); F. Enamel pattern of upper (?) third molar, *Phacochoerus altidens* Shaw and Cooke. (Natural size.)

South African Journal of Science, *Vol. XLII, pp. 236-239, June, 1946.*

MARINE ANIMALS IN A ROCK PAINTING NEAR FOURIESBURG, O.F.S.

BY

Dr. L. H. Wells,

Department of Anatomy, University of the Witwatersrand.

Read 2nd July, 1945.

At our 1944 meeting M. l'Abbé Breuil described paintings of undoubted marine animals (whale and shark) in the "Rose Cottage" Cave on the town-lands of Ladybrand, O.F.S. He also drew attention to a slab from the same area, now in the museum of the Archaelogical Survey at the University of the Witwatersrand, which has been interpreted as depicting a school of sea-fish being attacked by dolphins. As Breuil points out, Ladybrand is 210 miles from the sea as the crow flies, and Basutoland with its high mountains lies athwart this route. These paintings, therefore, raise the problem of communication between this inland region and the coast in prehistoric times.

Some remarkable paintings depicting fishing scenes were described at the same meeting by Mr. W. Battiss. He pointed out that these, like the representations of fish of which several examples have been recorded, do not necessarily imply any connection with the sea, although the scenes of fishing from boats suggest a considerable stretch of water.

In the discussion which followed these papers, I mentioned that in July, 1932, I had noted a painting, seemingly of marine animals, near Fouriesburg, O.F.S., also in the Caledon valley and nearly 200 miles from the sea. M. Breuil and Professor C. van Riet Lowe have urged me to put on record a description of this occurrence.

The site, on the farm Caledon Poort No. 190, Fouriesburg district, is a small rock-shelter on the right bank of the Little Caledon River a few hundred yards above its junction with the Caledon. This shelter is only a little above the level of the river, and below the road through the poort. The "Wyndford" guesthouse, situated on a portion of the farm Caledon Poort, is a short distance away; it seems probable that the entries Caledon Poort No. 190 and Wynford No. 190 in the Archaeological Survey's list of sites with paintings (van Riet Lowe, 1941) both refer to this shelter.

On the surface in the immediate vicinity of the shelter a number of small endscrapers and other artefacts were collected. These conform to the Smithfield C industry as defined by van

Riet Lowe (1929). Similar assemblages have been obtained from other shelters in the locality, including the classic painted site of Bester's Vlei, a few miles distant. In contrast with the circumscribed distribution of these Late Stone Age relics, a Middle Stone Age (Modderpoort) industry (Malan, 1942) is widely dispersed on the surface of this area.

The paintings in this shelter include several polychrome eland in an apparently late and somewhat impressionistic technique, and monochrome human and animal figures in dark red, orange and white. These range from a conventional but vigorous style to a degenerate crudity, a few examples of the latter being superimposed on paintings of better quality. In 1932 I traced most of the decipherable paintings, and from these tracings, reproductions in colour have been made for the Anatomy Department's files by the late Mrs. H. C. Swift.

Among the paintings in dark red monochrome is the group of fish-like creatures of which a tracing is shown in Fig. 1. M. l'Abbé Breuil agrees with me that the three figures on the right can only be identified as dolphins; this conclusion is based upon the contour of the body and the characteristic slender rostrum or beak. In the middle pair the impression is strengthened by the curve of the body, "with arched back, as it generally appears when rounding out to breathe" (Lull 1927), which recalls the conventional dolphins of European art. The tail is shown as bifid. which would be incorrect in an exact profile of the dolphin, while the number of fins indicated differs in each figure. Both of the middle pair of figures are given two dorsal fins, one at the head and the other close to the tail, where in reality the dolphin has a single mid-dorsal fin. One of them also has a fin half-way along the underside of the body; this might represent the pectoral flipper of the dolphin, but it is too far back. The largest figure has no fins at all. These discrepancies, howover, are not sufficient to overthrow the identification.) (See Fig. 1.)

The smaller of the two remaining figures obviously represents a fish. Whether the larger one on the extreme left is intended for a fish or a dolphin is less certain. The contour of head and body is very different from that of the other creatures in this painting, and may be compared both with the "dolphins" and with the larger fishes on the Archaeological Survey's slab. This figure has only one dorsal fin, placed very near the head; the irregularity of the ventral contour may be intended to indicate a pectoral fin.

To the left of this last figure is a group of human figures and objects suggesting quivers, also in dark red; a very crude animal in orange is superimposed on part of this group. There is, however, nothing to indicate a connection between the humans and the aquatic creatures.

The supposed dolphins on the Archaeological Survey's slab differ considerably in certain respects from those of the Caledon

Poort painting. In these figures the rostrum is less sharply defined and slender, although it is more elongated than in the associated fishes. There is a single dorsal fin well to the back as in dolphins, but the ventral fins correspond with those of fishes, viz., a pectoral and a pelvic pair, and a single anal fin between the latter and the tail. Nevertheless it may be concluded that in both pictures the artist has recognisably depicted the essential characteristics of the dolphin, even though his observation or memory has erred in various details.

This conclusion has a considerable bearing upon the problem offered by these paintings of marine creatures in an area far inland. In the opinion of M. Breuil: "We have to admit that the painters of these figures must have seen marine animals. Therefore they must have been to the sea." Under these conditions, unless the artists carried with them some sort of sketch, the paintings must have been made entirely from memory. There is no cause for surprise, therefore, that the artist, while preserving a vivid general impression of his subject, should have been mistaken or in doubt over details, and we cannot expect from him a recognition of differences between fishes and marine animals which are unknown to many Europeans, artists included.

If the range of travel demanded by M. Breuil's interpretation is considered impossible to the prehistoric artist, it must be supposed that these marine subjects were being reproduced at second or third hand or after an even longer traditional currency. Under such conditions conventionalisation would be inevitable. It is possible to accept the Caledon Poort dolphins as the results of such a process, but it is very difficult to believe that the artist of the Archaeological Survey's slab had not himself seen the incident which he depicted so vividly.

REFERENCES.

Battiss, W.: *This Journal*, Vol. 41, p. 356 (1944).

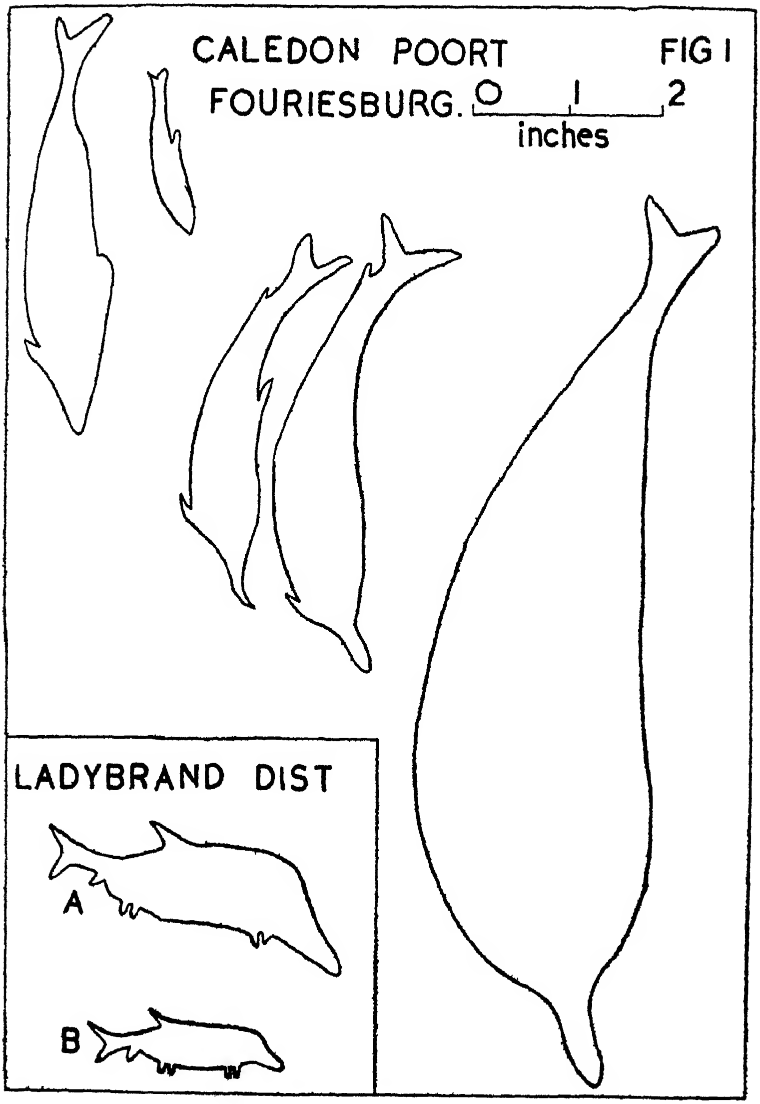
Breuil, H.: *This Journal*, Vol. 41, p. 353 (1944).

Lull, R. S.: "Organic Evolution," 2nd ed. New York: Macmillan. Chap. XIX, p. 743 (1929).

Malan, B. D.: "The Middle Stone Age of the Upper Caledon River Valley: The Modderpoort Culture." *Trans. Roy Soc. S. Afr.* **29**: pp. 113-127 (1942).

Van Riet Lowe, C.: "The Smithfield Industry in the Orange Free State" in "The Stone Age Cultures of South Africa" by A. J. H. Goodwin and C. van Riet Lowe. *Ann. S. Afr. Mus.* **27**: pp. 151-234 (1929).

"Prehistoric Art in South Africa," Arch. Ser. V. Bureau of Archaeology, Pretoria: Govt. Printer, 38 pp. (1941).


CALEDON POORT
FOURIESBURG.
FIG I
0 1 2
inches
LADYBRAND DIST
A
B

South African Journal of Science, *Vol. XLII, pp. 240-246, June, 1946.*

THE COASTAL SMITHFIELD AND BIPOLAR TECHNIQUE.

BY

C. van Riet Lowe,

Director, Archaeological Survey, Union of South Africa, Professor of Archaeology, University of the Witwatersrand.

Read 2nd July, 1945.

In 1936, Schofield described a new pebble industry which he related to the Smithfield Culture of the Later Stone Age. His description was based on collections from six different sites along a 59-mile stretch of the Natal coast. (Schofield, 1936.) The most interesting feature of the description centred on the fact that pebbles which formed the raw material were all of indurated shale, very water-worn, thin and small; the largest being more or less circular, less than two inches in diameter and less than one quarter of an inch in thickness. Schofield also illustrated a variety of tools which he described as scrapers (end, hollow and bevelled), points (rather like borers), backed blades (curved and straight-edge) made from fragments or on flakes struck from these small, more or less circular pebbles, and he concluded by saying that " the most fruitful comparison lies between our pebbles and implements of a Smithfield facies, more particularly the microliths of Smithfield C." In other words, he suggested that this hitherto undescribed pebble industry was possibly a coastal expression of the most developed Smithfield Culture, as its bearers were able to express themselves in the peculiarly shaped raw material available along the coast. The fact that at one site, the implements were derived from a deposit naturally stratified above advanced Middle Stone Age material and below remains of the earliest known Bantu culture in the area, and the discovery at the site, of bored stones and waste products which were neither Middle Stone Age nor Bantu, gave weight to his conclusions.

At the end of the same year (1936), Miss D. Walker found, at Richards Bay, about 100 miles north of Durban, a precisely similar assemblage of flat pebble artifacts and tools, but with many more thumb-nail scrapers. The pebbles from this new site are almost exclusively of indurated shale, but include a few thicker specimens in quartz. Those of indurated shale are all thin and small, and like the specimens found further south, more or less circular or elliptical; the quartz pebbles, on the other hand, tend generally to be more egg-shaped. Miss Walker also found the remains of a human burial and some potsherds at the site, but until a more thorough investigation into the possible

association of the bones, pottery and stones is possible, the report on the former is being held up.

This new discovery extended the distribution of this peculiar flat pebble, coastal culture from a strip of coast about 60 miles long, to one more than twice that length: from Karridene in the south to Richards Bay in the north. Despite the absence of bored stones and other elements which form an integral part of Smithfield "C," the preponderance of thumbnail scrapers and the absence of crescents in this new discovery gave the collection a much more Smithfield "C" appearance than did Schofield's material.

The most outstanding characteristic of these Natal occurrences, however, is the hitherto unrecorded fact that the pebbles were consistently fractured and splintered by a bipolar, percussion technique, i.e., the pebble to be split or flaked was held in a vertical position on a stone anvil and struck with a hammer-stone as indicated in Text Fig. 1. In this way flakes, spalls or splinters were often simultaneously removed from both ends or poles of the pebble, as well as from both faces, ultimately leaving a sharply bevelled bifaced chisel-like edge. More often than not, this edge is straight, but it is occasionally sufficiently curved to be more like a gouge than a chisel. This bipolar technique was responsible for the production of such tools as are illustrated by Schofield in his specimens numbered 3, 8, 9, 10, 11, 13, 14, 15, 16, etc., in Plate XI of his contribution previously referred to. The effect of bipolar fracture is most clearly seen in the first, and thus possibly one of the most characteristic artifacts selected for illustration by Schofield: No. 1, Fig. 2, Plate X. All the work on these specimens is primary. In other words, the shapes of the tools referred to were arrived at by perfectly straight-forward direct rest percussion, and bipolar trimming. In the absence of further deliberate or secondary trimming, such as we see in the specimen numbered 18 on Schofield's Plate XI, the term now generally applied to such tools as I have listed is chisel, not scraper; the basic technique followed in their manufacture is bipolar percussion, not pressure as Schofield suggested at the time. When such tools became blunted by wear, they could be resharpened by secondary trimming along the working edge and so become scrapers in the generally accepted sense of the term, but in the absence of such secondary trimming, they are chisels which fall within the French descriptive term *ciseau* or under the generic term *outils ècaillés*. Implements of this type occur both in the Middle and Later Stone Ages of South Africa. Malan has described them as *outils ècaillés* in the Stillbay (1939), and in the Modderpoort (1942) Cultures. They occur also in the Wilton, not only in Rhodesia and the Cape, but also in the Free State. In Kenya we find them in the Aurignacian (Leakey, 1931) and in Uganda in the Magosian and Wilton (Wayland and van Riet Lowe: in Press). They occur in the

deepest levels at Choukoutien (Pei, 1939) and, according to the Abbé Breuil, in the Aurignacian and Mesolithic industries in France, especially along the coastline and islands off the south coast of Brittany, at Sables d'Olonne, at Brive (Charante Inferieur), and at Mas d'Azil.

In his description of the Chinese specimens, Pei says: "Bipolar implements and flakes are very abundant in the Sinanthropus Locality 1, especially in the upper cultural zones. On the other hand, from Locality 15 we know very few specimens with indications of the bipolar process having been employed. On most of them we may find the clear trace of work on one side but not on the other (Fig. 16)"; yet it is most interesting to observe that both the implements illustrated by him in Fig. 16 could have been used to illustrate both European and African specimens from entirely different cultural horizons. In my Text Fig. 2, I have included one of the Choukoutien Locality 15 specimens for comparison with the South African specimen shown alongside.

Some of the illustrations of implements in the report on excavations carried out in the Bosumpra Cave at Abetifi, Kwahu in the Gold Coast Colony, suggest that bipolar fracture was also an integral part of the Guinea Neolithic, especially the implement described as a single faceted burin: No. 62, Fig. 4, as well as Nos. 69-73 in the same Fig., specimens which are not referred to in the text. The arrows suggest that they were also classified as burins (Shaw, 1944). These specimens have every appearance of being remains of cores from which flakes were removed by bipolar percussion. Such remains are common where this technique was practised on small water-worn pebbles, and inevitably they include scar-beds so arranged as to resemble burin facets, as shown in the four specimens in the bottom row of Text Fig. 2. While these artifacts are primarily remains of cores and, from their abundance on the site have every appearance of being waste products or débitage of the industry of the site and not tools designedly or deliberately made, the possibility that they were used as burins can not obviously be ruled out.

This bipolar technique is thus seen to be of very widespread occurrence. It is a manner of stone-fracture and stone-shaping common to many cultures and climes and not exclusively associated with any particular stone culture or time. Nevertheless its full significance was not appreciated until quite recently. For example, the type of tool produced under bipolar flaking was not generally known when Leakey described the Stone Age Cultures of Kenya Colony in 1931. Leakey referred to this type of tool as a "sinew frayer" and added that when he showed these "frayers" to the Abbé Breuil during the British Association meeting in Johannesburg in 1929, the Abbé "told me that similar tools certainly occur in some at least of the European Aurignacian sites, but that they have not been des-

cribed as a definite type." Schofield was in much the same difficulty in 1936. The importance of the tool and of the underlying bipolar technique were only recently recognised.

An interesting feature about bipolar fracture is the fact that while it appears to have been an extremely ancient practice in China, it seems to have been a comparatively recent discovery in Africa and Europe. So far as we know it was not practised here during the Early Stone Age at all. Its earliest application seems to have been during the time the most developed Levallois technique was in vogue in South Africa, i.e., during the Middle Stone Age, and possibly somewhat later in East Africa and Europe, viz., when the Aurignacian Culture was in full development.

The hammers and anvils call for special comment. The specimens chosen to illustrate the method of bipolar fracture sketched in Text Fig. 1, are actual and of average size. They are handy, ellipsoidal water-worn pebbles of quartzite or some equally resistant rock: three to four inches in length, two to three inches in breadth and two inches or less in depth. Both anvils and hammers are scarred: the latter over a small area or areas at the successive points of percussion; the former over a small area or areas at the successive points of contact between the pebble being fractured and the anvil. The extent and depth of each scar naturally depend on the severity, number and points of contact of successive blows, but once the effectiveness of either tool had been proved, it would obviously have been employed either as a hammer or as an anvil until well scarred not merely in one place but, as so many specimens show, in several places. The three specimens shown in the sketch, viz., the upper or hammer-stone, the intermediate pebble from which flakes have inevitably been removed from both ends, and the lower stone or anvil are all from the same site and are integral elements of the industry of the site. In the specimens selected for illustration, the upper stone, i.e., the hammer, has three scars: a more or less circular dimpled scar about half an inch in diameter on the lower face and scars at both ends, presumably due to finer or more controlled percussion. The lower stone or anvil has two adjacent deeply dimpled scars each about half an inch in diameter on one face, a third and deeper scar slightly less than one inch in diameter on the opposite face and heavily abraded patches at both ends and along the sides or edges. These two fabricators are obviously interchangeable; either could have been used first as a hammer and then as an anvil, and vice versa. The Text Figure merely outlines the principle of bipolar fracture and suggests probable usage of the specimens chosen for illustration. This principle is also very well explained and illustrated in Plate 20 of Pond's description of primitive methods of working stone, based on the experiments of Halvor Skavlem (1930.)

Whilst on a visit to Dr. C. H. T. D. Hesse at Riversdale in the Cape during February, 1945, the Abbé Breuil was taken

to a number of prehistoric sites in the district. Near the homestead of the farm Brakfontein about 15 miles S.W. of Riversdale and seven miles from the coast, the Abbé examined a rich Wilton site. While working outwards from the centre of this site, he came to a small calcified mound of sand on and in the immediate vicinity of which he collected a large number of stone implements and waste-products of human industry in cloudy-quartz and quartzite which bore no relationship whatever to the Wilton material less than 50 yards away. The Wilton site yielded a large and typical assortment of Wilton tools made, almost exclusively, of silcrete. The adjacent site on the other hand, yielded only a number of thumb-nail scrapers on cloudy quartz flakes struck from small flat or egg-shaped pebbles and fragments of pebbles split by bipolar percussion, a number of typical chisels on flat pebbles or fragments of flat pebbles shaped by bipolar percussion and several anvils and hammers of quartzite of the type shown in Text Fig. 1.

Not recognising the cultural horizon of this peculiar group of artifacts, the Abbé brought the collection he had made back to the museum of the Archaeological Survey. So far as he was concerned, this collection presented a new problem, but when I indicated the similarity between the specimens he had brought back from the Cape and those found by Schofield and Miss Walker along the Natal coast, and the common basic bipolar technique, he immediately urged me to complete this note for publication.

Two of the Brakfontein chisels made by bipolar percussion are shown in Text Fig. 2. With them I have included an illustration of one of Pei's specimens from Locality 15 at Choukoutien. In similar fashion, I could have matched certain of Leakey's Kenya Aurignacian specimens with others from Natal and so on, but the illustration I have chosen speaks, I think, for itself.

These Natal and Cape collections differ only in the thickness and nature of the pebbles used and taken together make it clear that we have along our coast, a most interesting Later Stone Age culture which, apart from the basic bipolar technique forced on the makers of the tools by the size and nature of the available raw material, has strong Smithfield affinities. Its main characteristics are so outstanding and it is so different from the Wilton, that I suggest it be known as Coastal Smithfield. Its tool types include the full range of thumb-nail scrapers which characterise the final Smithfield of the interior; with a single exception, the remaining types strike no discordant note. The only important differences between this coastal and the inland expressions of the main culture complex are the presence of the chisel and the intensive practice of bipolar flaking in the coastal area.

I wish, in conclusion, to express my indebtedness to Miss Jean Petrie of Nakuru, Kenya Colony, for having prepared Text Fig. 1 for me. We are also indebted to Miss D. Walker for

having gone to a great deal of trouble in rescuing the Richards Bay material, and to the Abbé Breuil for permission to use the unpublished information about bipolar fracture and trimming methods in the upper Palaeolithic and Mesolithic industries of France.

REFERENCES.

POND, A. W.: "Primitive Methods of Working Stone, Based on Experiments of Halvor L. Skavlem." *Logan Mus. Bull.* Vol. II, No. 1. The Logan Mus., Beloit College, Wisconsin (1930).

LEAKEY, L. S. B.: "The Stone Age Cultures of Kenya Colony." Camb. pp. 99-100 (1931). *This Journal*, **26**: 749-757 (1929).

SCHOFIELD, J. F.: "An Hitherto Undescribed Pebble Culture of the Later Stone Age from the Natal Coast." *Ann. Durban Mus.* **3**: Pt. 5, pp. 83—92 Illus. (1936).

PEI, W. C.: "A Preliminary Study of a New Palaeolithic Station known as Locality 15 within the Choukoutien Region." *Bull. Geol. Soc. China*, **19**: No. 2, pp. 147-187. Illus. (1939).

MALAN, B. D.: "A Description of the Hardy Middle Stone Age Collection. *Bur. of Arch., Arch Ser. No. III*, Illus. Govt. Printer, Pretoria. (Fig 6, Text Fig. E) (1939).

MALAN, B. D.: "The Middle Stone Age of the Upper Caledon River Valley: "The Modderpoort Culture." *Trans. Roy. Soc. S.A.* **29**: *Pt. II*, pp. 113-127. (Figs. 1, 2, 3. Pl X) (1942).

SHAW, C. T.: "Report on Excavation carried out in the Cave known as "Bosumpra," at Abetifi, Kwahu, Gold Coast Colony." *Proc. Prehist. Soc.* **10**: pp. 1-67. Illus. Cf. Nos. 62, 69, 70, 71, 72 and 73. Fig. 4, p. 8 (1944).

WAYLAND, E. J. and VAN RIET LOWE, C.: "The Pleistocene Geology and Prehistory of Uganda." Govt. Printer, Entebbe. (In Press).

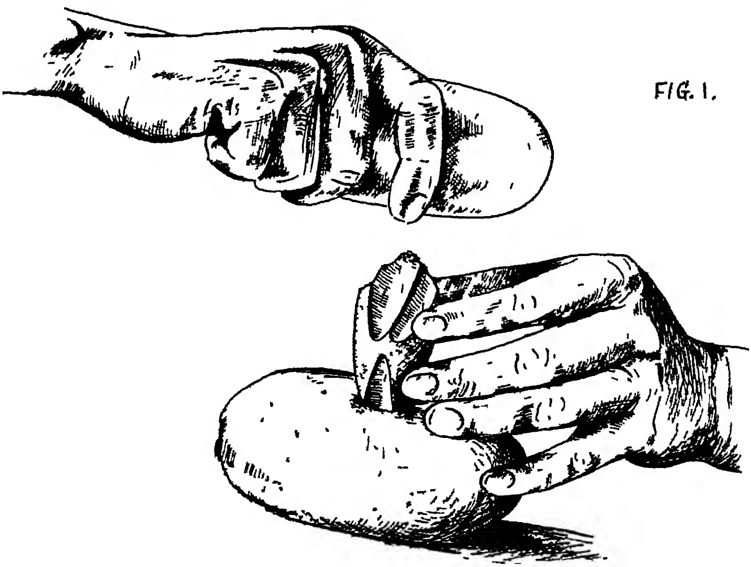
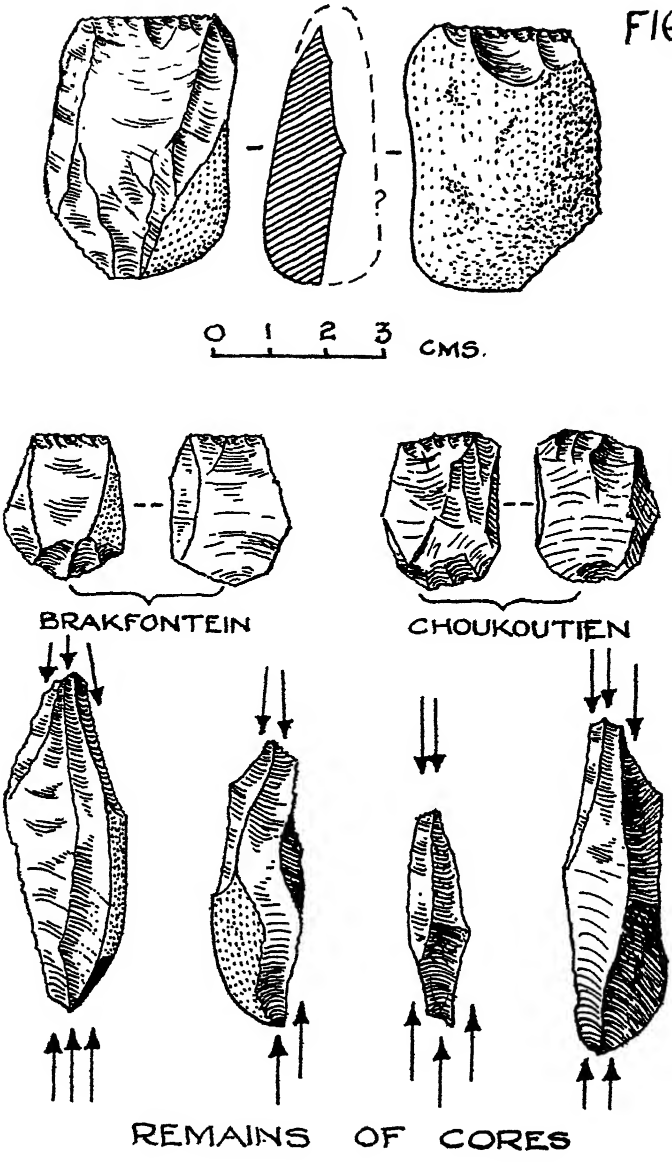


FIG. 1.

FIG. 2.



South African Journal of Science, *Vol. XLII, pp. 247-252, June, 1946.*

THE POSSIBLE DAWN OF ART IN SOUTH AFRICA

BY

C. van Riet Lowe,

Director, Archaeological Survey, Union of South Africa, Professor of Archaeology, University of the Witwatersrand.

Read 2nd July, 1945.

The first illustration which accompanies this descriptive note shows two peculiar fish-shaped artifacts recently discovered in South Africa. The upper specimen in Figure 1 is from the farm Koedoesdam adjoining Windsorton Road Station in the Kimberley district of the Cape of Good Hope. Both the reverse and obverse faces are shown. It was found on a flake recovered from an unusually extensive Fauresmith living-floor. The original flake and most of the secondary trimming are undoubtedly Fauresmith, but the edge opposite the detached dotted line was re-trimmed during the Middle Stone Age that followed. In other words, the secondary trimming, which extends over nearly 90% of the perimeter, is of two distinct periods, each of which is clearly revealed by the physical condition of the secondary scar-beds. The possibility of detecting this quality is due to the fact that the Fauresmith living-floor was partially exposed during the Middle Stone Age and that makers of tools of that period occupied the exposed area and made use of their predecessors' waste material. The physical condition of each group or assemblage of implements and artifacts is distinct. The material is indurated shale; the maximum dimensions of the specimen illustrated are 9.5 by 4.8 by 1.5 cms. in length, breadth and thickness respectively. It is impossible to say what the original (Fauresmith) shape of the artifact was, but the Middle Stone Age product is distinctly fish-like.

The lower specimen in the same figure is from the farm Longridge on the heights above the left bank of the Keurbooms river near its mouth at Plettenberg Bay. It is one of a large group of Stellenbosch implements recovered from a living-floor in a ferruginised sub-soil revealed by an extensive borrow-pit immediately alongside the main road from Plettenberg Bay to Port Elizabeth. All the implements (bifaced hand-axes and cleavers), and waste products (cores and flakes), recovered with the specimen illustrated, are typical products of an advanced Stellenbosch industry of the African Acheulean culture complex.

While the flared tail-end might have been a cleaver, the remainder would, if deprived of the tail, be taken to be a much damaged fragment of a typical bifaced handaxe. The artifact is

trimmed entirely over one face and almost entirely over the other face. The " dorsal " and " ventral " edges as well as the edges that form the hollow that leads to the tail show considerable bruising—as though the fish-like shape was achieved by hammering and battering after the form had been flaked into shape in the usual manner. The effects of this battering extend over the entire perimeter except the extreme end of the " tail," which was partially damaged during recent quarrying. The result of this battering is a completely blunted and roughly rounded edge which it is difficult to illustrate. Only the tail-end has sharp arrisses. In cross-section, the body of the artifact is oval rather than biconvex or lenticular. This purposeful battering of the edges reveals a shaping process which, apart from this specimen, is not known to have been practised during the Earliar Stone Age and is sufficient to mark the artifact as extremely unusual, if not unique. The material is Table Mountain Sandstone, and all the scars exposed by flaking and battering are equally weathered. Maximum dimensions are 29.0 by 11.5 by 6.0 cms. in length, breadth and thickness respectively. There can be no doubt that it belongs to the Stellenbosch Culture.

These two artifacts, each of which is unique in its setting. present a new problem. Are they tools or are they early attempts at sculpturing? If they are tools, they represent new and hitherto unrecorded forms; if they are attempts to depict fish, they throw an entirely new light on the age of the awakening artist in man. The oldest art hitherto recognised in South Africa may belong to the Middle Stone Age, but we cannot yet be certain that it takes us further back in time than the Later Stone Age. To find any deliberate excursion into the world of art in the Middle Stone Age would not be unexpected, but to trace it into the Earlier Stone Age is decidedly revolutionary.

In addition to the skill, imagination and genius that are required of an artist, the artist himself needs the leisure in which to experiment and express himself. He may have enjoyed this during the Earlier Stone Age, but the rigorous and entirely exposed life he led does not suggest much leisure. Yet the tools he made and the technical processes he practised, after he had mastered the Proto-Levallois technique that is part and parcel of the Stellenbosch Culture of the advanced African Acheulean type, certainly suggest such skill, imagination, pride in craftsmanship and genius as we usually associate with sapient man. His well-made slender and symmetrical hand-axes and cleavers and the techniques he practised in their manufacture, not only show marked ability and imagination, but reflect an innate pride in the production of objects, many of which can only be faithfully described as " works of art," despite their supposedly utilitarian purposes. Starting on a core often as large as his torso, the maker of our Acheul-type implements detached flakes from individual specimens of which he could have made half-a-dozen hand-axes or cleavers. We have individual primary flakes as large as a leg

of mutton! To detach such immense flakes calls for exceptional skill. One has only to try to do it oneself to realise that possibly some mechanical contrivance, such as a suspended boulder drawn to one side and released as a pendulum aimed at the core from which flakes were to be struck, is needed. To drop a boulder to act as a " detaching-hammer " from a height above the core, or to drop the core from a height on to a suitable " anvil " would perhaps be equally effective, but obviously not so accurate. Whatever this prehistoric forerunner of ours did, he undoubtedly possessed unusual strength, skill, craftsmanship and imagination. His mind was not wholly that of a brute.

Utilising these large flakes as "cores " and the scar-beds as striking platforms, he continued to detach flakes which he converted into hand-axes, picks or cleavers until the core was reduced to about the size of his head. He then prepared what was left, more or less in the classical Levallois manner, i.e., he trimmed it radially toward the centre on the upper (flatter) face as well as on the lower (high-backed) face, and after he had prepared a suitable striking platform, struck the final flake which he converted into the tool he needed: a shapely hand-axe or cleaver (end- or side-cutting), or a scraper. One cannot accuse such a craftsman of lack of imagination. To be able to visualise a six-inch biface or a whole series of such bifaced tools in a sixteen-inch or twenty-six-inch diameter core and to have the skill to reduce it as methodically and as artfully as the masters of the Proto-Levallois technique did, is by no means a mean feat. Add to this the fact that his living- and working-floors often contain hundreds of discarded hand-axes and cleavers which are suitable for exhibition in museums, we realise that he was not easily satisfied. He had certain standards below which he would not fall where he had a sufficiency of material. In other words, he was exacting and particular; he took a pride in his work and in doing so, revealed the potential, if not the actual artist within.

We know that true art has its one end in itself and that it rejects every extraneous purpose, and we know also that any utilitarian work is not yet generally considered to be a genuine work of art, but as Baldwin Brown has asked, " *is* it true of art in general or of art in these early manifestations that we have been considering?" (1928). The thesis that while such stone implements as we find in the upper Stellenbosch of such marked Acheulean affinities were always instruments or essentially things of use, but that their utilitarian purposes do not necessarily preclude some of them being at the same time works of art, was critically examined by the Abbé Breuil as long as twenty years ago (1925-1926). While he acknowledged that figurative art only began in the Aurignacian phase of man's development, he nevertheless stressed the fact that during Acheulean times and even earlier, " there is manifested a certain artistic sentiment in the regularity and the proportions of the best of the implements; " we recognise," he continues, " that this sentiment is a proof

of a fundamental aptitude for making a work of art, but we cannot affirm that the beauty of a work had yet come to be realised independently of its practical utility." The Abbè believes that good craftsmanship must result in a certain beauty although the craftsman himself may not necessarily be conscious of this. Nevertheless he credits such craftsmen as we find in Acheulean times, both in Europe and in Africa, with an appreciation of the aesthetic aspect of his works—a belief which I whole-heartedly share, especially in Africa where the coarser grained and less tractible quartzites present many more difficulties than the fine-grained and more homogeneous flints of north-western Europe. With Baldwin Brown, I therefore feel that there need be no reluctance in principle to apply the term "work of art" to some of the Palaeolithic or Earlier Stone Age products.

It would therefore not surprise me to find that an occasional artist indulged in his art for purely aesthetic reasons, towards the culminating stages of the Earlier Stone Age when one of the processes of making hand-axes and cleavers was to trim flakes carefully struck from deliberately prepared cores. Whether the specimen illustrated was deliberately shaped to resemble a fish or not is, of course, another matter. We cannot say, yet we should, I feel, retain an open mind and recognise the possibility that the birth of 'art for art's sake' may have occurred in Africa during the Great Hand-Axe Culture of Upper Middle Pleistocene times.

Cleavers with flared "working-ends" are not common, but quite a number have been recorded in Stellenbosch III and IV assemblages. The majority belong to IV. A group is shown in outline in Text Fig 2. Of the five illustrated, No. 2 is the only specimen which is clearly on a base-flake struck in the Proto-Levallois II manner. The broadly faceted striking-platform is shown in the sketch. No. 4 is also on a base-flake, but secondary trimming has entirely destroyed both the tell-tale platform and face. Nos. 3 and 5 are on oblique flakes, the direction of the blow being indicated by an arrow. Striking platforms have been entirely removed by secondary trimming. No. 1 is on a side-flake struck from a larger flake. It is from an advanced Stellenbosch assemblage from Paarl. The remainder are from the Vaal: No. 2 from a Stellenbosch IV assemblage from Riverview Estates, No. 4 from a similar assemblage from Sheppard Island, and Nos. 3 and 5 are from Christiana, possibly from Stellenbosch III assemblages. Both are well-rolled specimens from the body of Younger Cravels III. All reveal an unusual skill and pride in craftsmanship which suggest the type of genius which we cannot dissociate from artistic as distinct from purely creative ability. This pride in craftsmanship was not purely instinctive; it rather reveals a social phenomenon which is a necessary ingredient in an art-conscious community.

When I discussed my views about these artifacts with the Abbè Breuil, just prior to his return to Europe last month, I

found him in complete agreement with me. He has seen and handled the specimens illustrated and is therefore in a sound position to form his own opinions. At the same time he drew my attention to two interesting discoveries he made in Europe years ago. The first concerns a partially shaped slab of flint he recovered from a river gravel at Rochy-Condé (Oise) in 1900, which yielded Acheulean and Old Levalloisian implements. This artificially shaped fragment resembles the head of a ruminant, but it has unfortunately not yet been published, despite the fact that the Abbè mentioned it at the First International Congress of Anthropologists and Prehistoric Archaeologists held in Paris in 1900. It is, he hopes, still in the Institute of Human Palaeontology in Paris. It measures about six inches in length and was artifically shaped by a flaking process over nearly two-thirds of its perimeter. In addition, a suitably placed natural projection was removed to form an eye.

His second discovery was that of a deer in flint. Whilst classifying Dr. Lalanne's large Cap Blanc collection in 1914, he paid special attention to the dual purpose piercer-cum-hollow-scraper tools. Among these he inevitably found many peculiar shapes, one of which was clearly the figure of a deer. He asked the doctor to keep this specimen carefully on one side. Six years later the Abbé Bouyssonnie rediscovered the figure independently and described it. Although it belongs to a culture when art was already well developed (the Magdalenian), it is unique in its setting and extremely interesting.

These few illustrations show that such rare and unusual discoveries should not be ignored and classed as freaks either of nature or of man's whimsicality, but should be preserved and described, as the dawn of art may be much more remote in time than we have hitherto believed to be the case.

REFERENCES.

BREUIL, HENRI: "Les Origines de L'Art." *Jour. de Psychologie*, **22**: (1925).

BREUIL, HENRI: "Les Origines de L'Art Decoratif." *Jour. de Psychologie*." **23**: (1926).

BALDWIN BROWN: "The Art of the Cave Dweller." John Murray (1928).

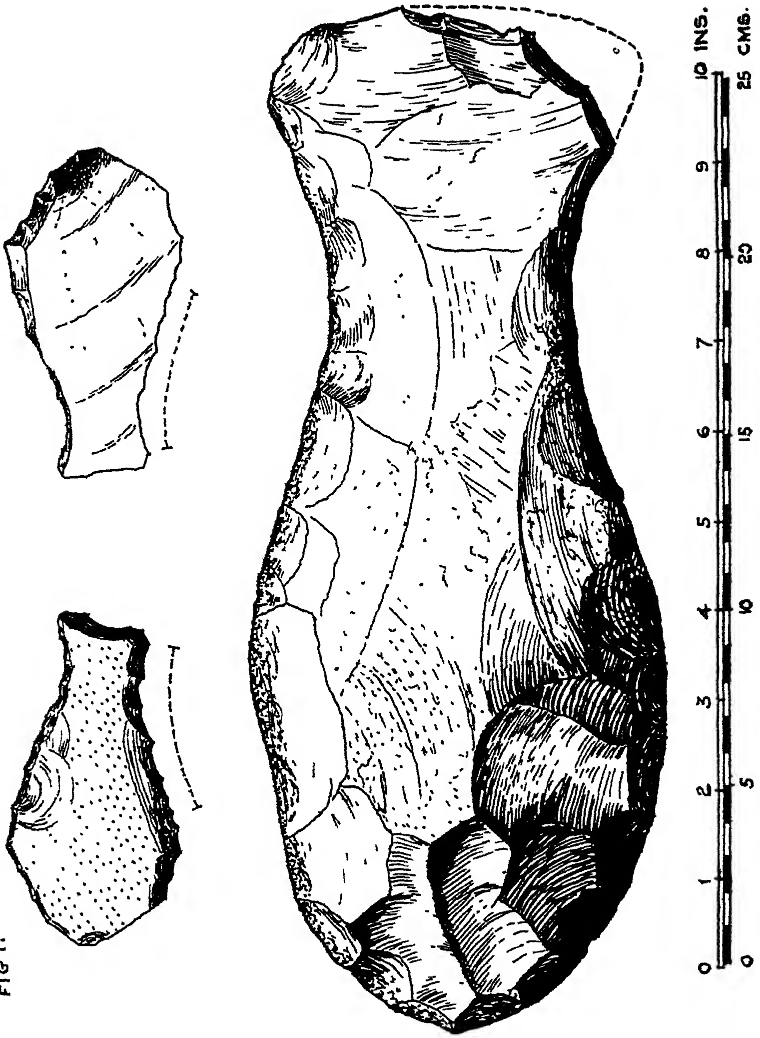
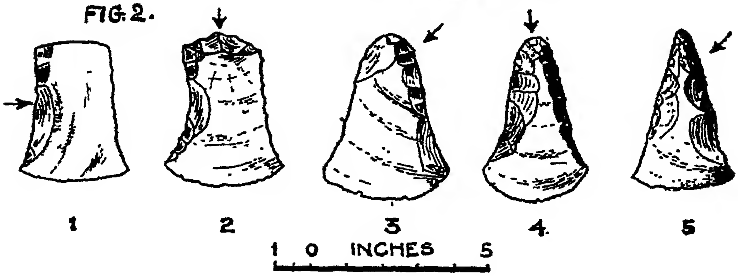


FIG 1.

FIG. 2.



SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XLII, p. 253, June, 1946.*

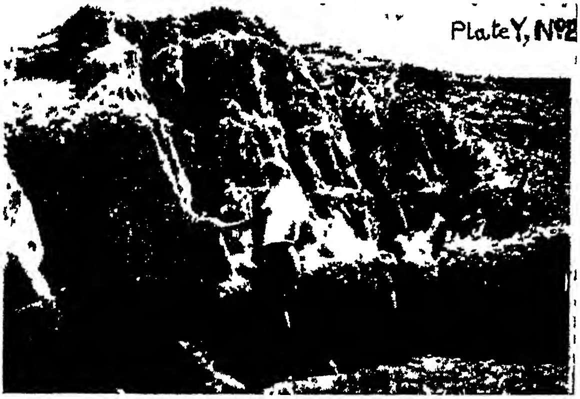
PIETERSBURG DONGAS AND TYPES

BY
JOHN HARCUS.

Read 3rd July, 1945.

Abstract.

(1) *The Dongas.*—Between Nylstroom and North Pietersburg tons of Artifact material have been found in several areas each about a square mile in extent and sunk from six to twelve feet below ground level. Their surface is generally yellow ou 'klip with many pebbles mixed with chips, flakes and stone tools. Plate Y, No. 2 shows a bank of Salusbury Donga with four narrow bands of pebbles, indicating four occupational periods and four bands of soil and sand averaging 2 ft. 2 in. in width, indicating unoccupied periods of probably 500 years duration each.



(2) *Some Core Types.*—About a fourth part of the cores found in these dongas are of three types. Type A is a thick discoidal core with a fairly circular disc, scalloped edges and short scars, from 5 in. to 3in. in diameter and 1¾ in. thick. Type B is a " Tortoise " core, shaped like the carapace of a tortoise, with diameters 6 in. and 4¾ in., and 3in. thick, highly arched above, the apex being 2 in. above the scalloped rim, and slightly convex below. Type C is a smaller and flatter disc averaging 3 in. by 1½ in., with sharp scalloped edges, possibly of use as a cutting weapon thrown by hand or from a sling.

(3) *Bifaced Points.*—Three specimens of a rare type from Uitloop, Toland and Harcus dongas are described. They are in a coarse slightly granular red felsite, all without patina, and fully worked on both face and reverse, with a preliminary reduced bulb on the reverse and with rugged scalloping along both edges. They are respectively 3½ in. by 1½ in. width at base by ½ in. thick. 4¼ in. by 1⅝ in. by ½ in. and 4 in. by 1⅞ in. by ⅝ in.

South African Journal of Science, *Vol. XLII, pp. 254-260, June, 1946.*

THE DISTRIBUTION AND CHRONOLOGY OF THE MODDERPOORT CULTURE

BY

B. D. Malan,

Bureau of Archaeology, Johannesburg.

Read 3rd July, 1945.

When I originally described the Modderpoort Culture (1942), its known distribution was confined to five sites in the Caledon River valley, forming the boundary between the Orange Free State and Basutoland. They lie between Rydal Mount in the north and the type-site at Modderpoort in the south. Since then a number of discoveries have been made which not only extend the area of distribution of this Culture, but raise a number of important considerations in regard to its chronology and morphological affinities.

Whilst my paper was in the press the excavations at Mapungubwe on the Limpopo, some fifty miles due west of Messina in the Northern Transvaal, revealed an interesting deposit from which Professor van Riet Lowe recovered a small series of material typologically identical with the material from Modderpoort. A full description of this hitherto undescribed material will be included in the second volume on the excavations at Mapungubwe, but with Professor van Riet Lowe's permission I shall give a brief description of the principal elements of this industry. Before doing so it is interesting to observe the remarkable similarity between the type site at Modderpoort and the Mapungubwe occurrence. Both sites lie on summits of precipitous flat-topped heights of Cave Sandstone, to which the materials for making implements were brought from considerable distances. Both sites afforded similar protection, and identical materials were collected to make artefacts which are typologically indistinguishable. The Modderpoort horizon on both sites lies between deposits of sands which are superficially the same. The occupants of the Modderpoort and of the Mapungubwe heights therefore not only made tools of similar type, but chose similar habitats and environments. All this suggests an identity of outlook and mode of life which lends considerable support to our identification of the lithic industry of Mapungubwe with that of Modderpoort.

On Mapungubwe the following stratigraphical sequence is represented:

Mapungubwe (early Bantu) deposit, 0 to 7 feet.
Wind-blown yellowish sand, 7 to 10 feet.
Modderpoort Industry, 10 feet to 10 feet 3 inches.

Reddish Earth, 10 feet 3 inches to about 10 feet six inches.
Bedrock, about 10 feet six inches.

A small collection now in the museum of the Archaeological Survey consists mostly of factory site debitage. The materials used were white cloudy quartz, cherts, agates, fine-grained sandstones and coarser quartzites. The artefacts are small, as will be seen in Figure 1. The technique is very advanced Levallois, with some evidence of bipolar or direct rest percussion fracture on rounded pebbles. This latter technique has been fully described by van Riet Lowe (1945). The flakes and blades are extremely thin, with well faceted striking platforms. Figure I, 5 represents the smallest complete Levallois flake with faceted striking platform that I have seen; it is no larger than a threepenny piece but shows all the characteristics associated with the Levallois technique. The tools contained in the collection include a carefully trimmed point with reduced bulb (Figure I. 1), a small point without secondary trimming (Figure I, 6) and two backed blades, which though small, are of Middle Stone Age type rather than microliths. (Figure I, 7, 8). A typical core in fine-grained sandstone (Figure I, 3) and a smaller core in cloudy quartz (Figure I, 4) are also illustrated. Figure I, 2 is a typical radially prepared Levallois flake.

On the nearby farm Parma No. 591, Mr. J. S. Schofield discovered a similar occurrence of very advanced Middle Stone Age material under several feet of accumulated Mapungubwe cultural remains. A fully representative collection from this site is at our disposal. On superficial examination this material falls into two very obvious groups: one consists of specimens in cherts and fine-grained quartzites which are sharp and fresh, with little alteration through weathering; the other group is made up of fine-grained porphyritic basalt, much leached-out and encrusted, with the arrisses rounded by weathering. The specimens in cherts and quartzites are generally smaller and more refined in appearance than those in the other group. The flakes and blades in the porphyritic basalt group are typologically more reminiscent of an early or middle phase of the Middle Stone Age, but this group nevertheless includes a number of small, advanced Levallois cores which suggests that both groups are integral parts of the same industry. It must also be remembered that a similar state of affairs exists at the type site of the Modderpoort Culture where sandstones were used for the larger implements and cherts for the smaller specimens of the same industry. It should also be borne in mind that the porphyritic basalt weathers more rapidly than the cherts and fine-grained quartzites and quickly develops a yellowish-brown crust, a fact which might well account for the difference in physical condition between the two groups. The same state of affairs is present at the type site, where less resistant sandstones were used for the larger implements. All things considered, we are therefore inclined to regard the two groups as forming integral parts of the same industry, but the point is open to reconsideration in the light of further evidence.

Figure II illustrates a number of specimens from this site. Nos. 1 and 2 are a weathered blade and core of hornfels; Nos. 3 and 4 are a thin flake and blade respectively in chert; No. 5 is a diminutive advanced core from which a flake has been struck, with a prepared platform for striking a second flake, probably from the other as yet unstruck face. No. 6 is a small carefully trimmed point on a convergent longitudinal Levallois flake; Nos. 7 and 8 are backed blades in chert, quite clearly of Middle Stone Age type and quite unlike microlithic forms of crescents.

La Reve No. 614 is another farm on the Limpopo river adjoining Mapungubwe. About a dozen specimens found on the surface here are just sufficient to indicate that the site is a mixed one and contains elements of the Modderpoort Culture as well as typical Later Stone Age endscrapers and debitage.

This completes our survey of sites on the Limpopo. More recently a re-examination of the extensive collections from various sites in Griqualand West presented to the Archaeological Survey by Mr. J. A. Swan of Kimberley, who has for many years made invaluable contributions to the Museum of the Survey, has led to the recognition of Modderpoort types in at least four sites in that area: Pniel, Rooipoort, Kimberley and Witsands in the districts of Barkly West, Kimberley and Hay. From Pniel comes a solitary point (Figure III, 1) which is so characteristic of the Modderpoort Culture that its identification is beyond question. It is of purplish chert and is made on a convergent longitudinal advanced Levallois flake with carefully prepared striking platforms. The secondary trimming is very careful and consists of the removal of very small thin flakes, while the bulb of percussion has been reduced by the removal of two very thin transverse flakes.

Eroded areas on the bank of the Vaal on the farms Klipfontein and Berg Plaats, district Kimberley, which together with the adjoining farms constitute the Rooipoort Shooting Box of the De Beers Company, have yielded collections of middle and late Smithfield industries. Amongst these we found seven specimens which belong to the Modderpoort Culture and differ radically from the Smithfield material with which they are in superficial association. We illustrate two small very advanced Levallois cores and side scrapers, a backed blade and a small point (Figure IV, 5—8). The circular core is of indurated shale, the triangular one is of chert, while the side scraper is of banded ironstone.

From the vicinity of Kimberley itself come about a dozen pieces of Modderpoort type, those illustrated (Figure IV, 1—4) being two small advanced Levallois cores, a rather thick bifaced point and a thick scraper. The remaining specimens in this group include two more triangular cores similar to those illustrated from this site and a side scraper and two more points on Levallois flakes of comparable size and degree of refinement, with most carefully faceted striking platforms.

On the farm Witsands on the West side of the Langeberg in the district of Hay, Mr. Swan discovered two sites close together. Among loose slowly moving sand-dunes Mr. Swan found a rich area of Free State Wilton occupation with many small crescents, end-scrapers, thumb-nails and other microliths in banded ironstone. About three miles to the north he found a Middle Stone Age site at which two materials were used: jaspery banded ironstone and rather coarse-grained grey quartzite. The collection made here includes no cores, but the flakes and blades in the banded ironstone are extremely slender and have scrupulously prepared striking platforms. Convergent longitudinal primary flaking occurs, but radial primary work predominates. The secondary trimming shows high skill and is refined in character. The disadvantages inherent in the laminated nature of the material are skilfully overcome by working obliquely to the natural planes of weakness in the rock.

The most numerous tool types are small trimmed points. (Figure III, 2, 3, 5) and blades which have been trimmed along one or both edges on the upper faces to form side-scrapers (Figure III, 4); the collection includes one graver (Figure III, 6). Although this material has fairly sharp edges, it has undergone leaching by weathering and lacks the high lustre and freshness of specimens of comparable material from the neighbouring Wilton site.

The tools in grey quartzite are generally larger and apparently more crude, but allowance must here be made for the differences in the fracturing characteristics of the two materials. On the quartzite specimens the convergent longitudinal technique predominates. Striking platforms are faceted, but the flakes are generally thick. Secondary trimming is not extensive and many artefacts which may be presumed to have been useful tools have no secondary work. An exceptional slender blade in this material shows well-controlled parallel flaking and is no less advanced than the specimens in banded ironstone.

This site shows an interesting parallel with the type site at Modderpoort where the bulk of the material is chert, agate and chalcedony, but fine-grained sandstones were used for the larger tools.

Much new light is being thrown on the Modderpoort Culture by excavations which are still in progress in a cave known as Rose Cottage Cave on the town lands of Ladybrand. This site is only some six miles on an airline from the type site on the mountain behind Modderpoort railway junction. The Abbé Breuil's intensive work on the rock paintings of this and other caves in the district as well as my excavations will be fully published when the work has been completed. It is sufficient for our present purpose to outline very briefly the results so far obtained.

Although the greatest depth so far reached is thirteen feet six inches, bedrock has not been exposed. The upper levels contain a microlithic industry with a very small specialised form

of crescent, many endscrapers, short bone points and other implements which lead us to identify the industry with a special expression of the Wilton Culture which we provisionally designate the Orange Free State Wilton. This culture is known from a large number of surface sites, in the Orange Free State and Griqualand West, where it also contains delicate bifaced tanged arrowheads, beautifully made by means of careful pressure-flaking.

Underlying the Free State Wilton in Rose Cottage Cave is a microlithic industry with much debitage and very few recognisable tools, the most numerous of which are slender microlithic blades with erratic secondary flaking on the flake surfaces apparently resulting from use. It is hoped that further work in the cave this season will enable us to form a clearer picture of the industry. Under this as yet unidentified industry, is a considerable thickness of all but sterile yellow sand. Below this occurs a black layer consisting of hearths containing an excellent normal expression of the Modderpoort Culture. A deep donga on the mountain-top above the cave also yielded a number of pieces which are easily identified with the Modderpoort Culture.

Discussion.

All this new work has thrown considerable additional light on our problem, but it has also raised certain difficulties on which we can at present only speculate.

The excavations in Rose Cottage Cave show stratigraphically that the Modderpoort Culture formed the link between the Middle Stone Age and the Later Stone Age. at least in the region of the middle Caledon river valley. It was however separated from the true Free State Wilton by a considerable period of time, as evidenced by the considerable thickness of yellow almost sterile sand and of the as yet unidentified microlithic industry which lies between the Modderpoort and the Free State Wilton in Rose Cottage Cave.

When we come to consider the relationship between the Modderpoort and Magosian cultures the position is not so clear. After discussing this question briefly in my original description of the Modderpoort Culture I rejected the possibility of identifying it with the Magosian on typological grounds and on the fact that the few microlithic elements present on the type site could well be due to admixture in an area which was the known hunting-ground of Later Stone Age peoples. The discovery of the Modderpoort Culture as far north as the Limpopo river reopens this question. This gives us a distributional link with Neville Jones's site at Sawmills, Southern Rhodesia, which cannot be ignored. In a recent contribution (1945) Neville Jones writes: " This ' Sawmills Industry ' as I originally termed it, is regarded by Dr. Leakey (1936, p. 123) as attributable, on typological grounds, to the Magosian Culture . . . . I am quite satisfied to take Dr. Leakey's opinion and to apply the term ' Magosian ' to what I have hitherto called the ' Sawmills

Industry.' Its main character is the cultural association of a highly developed Levallois technique with microliths which foreshadows the Wilton Culture. This association seems to me capable of two possible interpretations. The first is that it represents a nexus between the Middle and Late Stone Ages, in which case it might appear that the Wilton is a direct development from the Still Bay; and the second is that, it represents a sporadic grafting of an immigrant race onto a late survival of Middle Stone Age times, in which sense it may be regarded as a dead end." Neville Jones prefers the second interpretation because of the rarity of Magosian occurrences and because " the sudden break off of the Levallois tradition is also significant."

Apart from a small and rather inadequate series from Sawmills I have no Magosian collection at my disposal, but it is clear that, while the Levallois forms in the Magosian may be identical with those of the Modderpoort, the latter lacks the microlithic elements of the Magosian. The Modderpoort Culture, indeed, is made up of what might be termed the Levallois half of the Magosian, and is therefore regarded as slightly more primitive.

Stated in terms of Neville Jones's two alternatives, the Modderpoort may be the final Middle Stone Age Culture on to which the microlithic elements were grafted in Rhodesia and further North, or it may represent a nexus in the evolution from the Middle Stone Age to the Magosian. Of these possibilities I prefer the latter because in Rose Cottage Cave, the Modderpoort is separated from the Wilton by a considerable space of time. On theoretical grounds it seems likely that, if an equivalent of the Magosian is yet to be found in our area, it should fall within the period which separates the Modderpoort from the Free State Wilton, and that the Modderpoort or its equivalent is yet to be discovered further north to fill a gap between the Middle Stone Age and the Magosian in those regions.

ACKNOWLEDGMENTS.

I wish to express my thanks to Prof. van Riet Lowe for permission to use the material from Mapungubwe, and to Mr. E. Mendelsohn of the Department of Geology, University of the Witwatersrand, who kindly identified the fine-grained porphyritic basalt from Parma. Finally I must record my ever-increasing debt to Mr. J. A. Swan for the materials from the Kimberley area.

REFERENCES.

MALAN, B. D.: "The Middle Stone Age of the Upper Caledon River Valley: The Modderpoort Culture." *Trans. Roy. Soc. S. Afr.* **29:** Pt. II (1942).

VAN RIET LOWE, C.: "The Coastal Smithfield and Bipolar Technique." *This Journal,* **41:** (1945).

JONES, NEVILLE: "The Climatic and Cultural Sequences at Sawmills, Southern Rhodesia." *Occ. Papers. Nat. Mus. of S. Rhod.* **11:** (1945).

FIG 1 MAPUNGUBWE

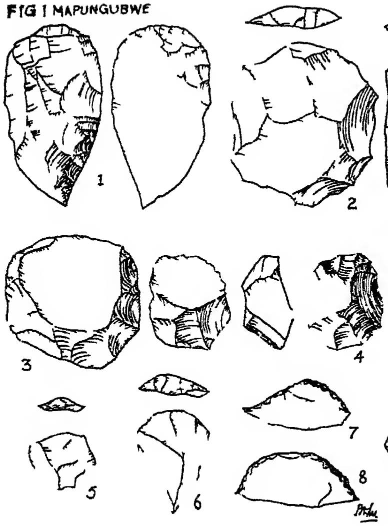


FIG 2 PARMA

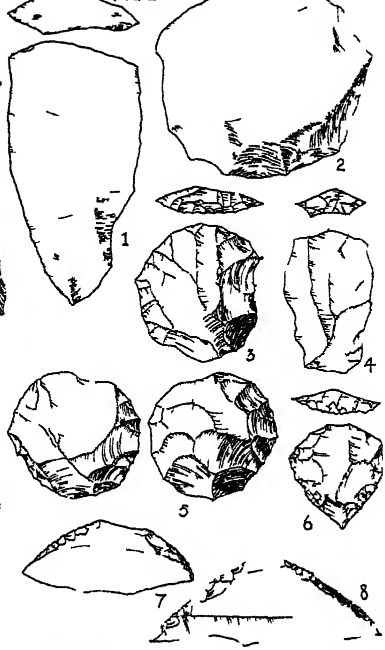
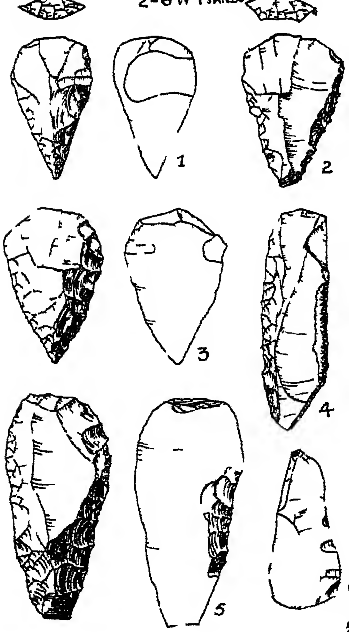


FIG III 1-PNIEL 2-6 W TSANDS



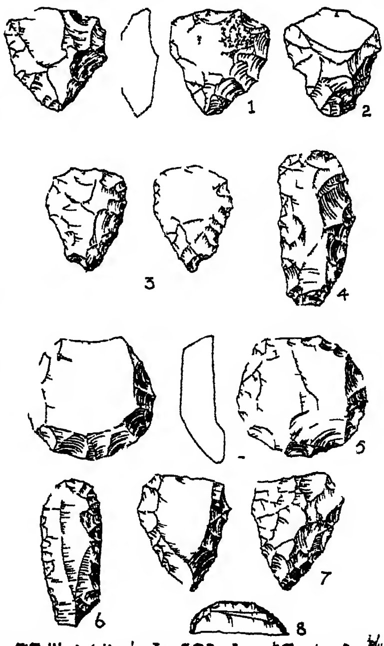


FIG IV 1-4 Kimberley 5-8 Rooipoort Shooting Box

South African Journal of Science, *Vol. XLII, pp. 261-268, June, 1946.*

SOME FURTHER OBSERVATIONS ON THE UPPER ORANGE RIVER IN RELATION TO CRUSTAL MOVEMENT AND THE STONE AGE

BY

D. R. Macfarlane,

Observatory Boys' High School, Cape Town.

Read 3rd July, 1945.

In 1944 (this Journal, Vol. 41) the writer recorded his observations on the High Level Gravels at Aliwal North. Since then, a further examination of the gravel deposits lying further afield has been undertaken in a survey up the left bank of the Orange River from Aliwal North to the Hot Springs at Badsfontein, and down the right bank of the Orange from Aliwal North, to the old Klipfontein diamond diggings, and in the immediate area of the hot spring at Badsfontein.

The Farm Oorlogsfontein.—This farm lies in the confluence of the Kraai and Orange Rivers and was examined for evidence indicating the former course of the Orange River, as it was postulated by the writer, in this Journal in 1944, that the Orange had, before changing its course, flowed along the foot of the Oorlogsfonteinberg. This is indeed proved to be the case; a spread of gravel similar to that on the Orange and Kraai Rivers being located at a height of 275 feet above the rivers on a well-defined sandstone scarp; two other parallel scarps rise above this arranged *en echelon*, fading out in the vicinity of the Homestead. The highest scarp emerges again and trends towards the Kraai River Poort. There is a marked depression at the foot of the berg below this scarp which is not in evidence below the others, while the vlei on the left bank of the Kraai appears to be a continuation of this depression. The salient features of the area are shown in the Sketch Fig I.

The first impression is, that the scarps and accompanying terraces have been cut by the Orange, but on closer examination, their characteristic slight bending along their lengths and the slight inward dip of the strata of the first scarp together with the fading out of the scarps, at once suggests that they are the result of faulting; if so, they are in keeping with the observed phenomena of the Aliwal North basin. The fault thus appears as a continuation of the Kraai River fault, hinged along the flank of the Oorlogsfonteinberg, and suggesting the phenomena known as trap-door faulting.

The implements derived from the surface of the gravel above the first scarp are shown in Fig. 4., Nos. 4, 5, 6, 7, 8 and 9. They are all of a Middle Stone Age facies and show various states

of rolling: No. 4 (quartzite) is slightly rolled, No. 5 (lydianite) shows slightly more abrasion, while No. 6 is comparatively fresh. No. 7 (lydianite) is well rolled, while Nos. 8 (quartzite) and 9 are heavily rolled and more primitive in technique.

No direct evidence of faulting was observed in either the Kraai or the Orange River breaches of the Oorlogsfonteinberg, but behind the berg the typical rises and depressions are again in evidence, more particularly on the farm Zonnenbloem. A study of the topography of the area suggests that the former course of the Kraai ran along the foot of the berg, entering the Orange just above the poort, but this longitudinal depression may be due to other causes.

There is a characteristic river gravel mound on the farm Zonnenbloem, situated about a quarter of a mile from the Orange and standing about 140 ft. above its bed (Fig. 2). The mound is higher than much of the surrounding area and has a typically humped appearance; implements derived from its surface are heavily rolled and appear to be of a M.S.A. facies (Fig. 4 Nos. 12 and 13); no excavating or digging for diamonds has been done on the mound. Four hundred yards away on the neighbouring farm of Ellerslea is another mound (Fig. 2) standing about 70 ft. above the river; this has been extensively worked for diamonds and rolled implements were found in the exposed faces of the various pits, which also appear to be of a M.S.A. facies. The sandstone underlying the mound has the characteristic dip of 1½°. Apart from the difference in the heights of the mounds, whose deposits appear to have been laid down at the same time, no other evidence of movement was noticed.

Above Ellerslea, the river narrows, often running between high sandstone cliffs and across dolerite dykes. No gravel deposits were noticed between Ellerslea and the hot springs at Badsfontein.

The Badsfontein Hot and Cold Springs.—These are situated in a cleft in the high sandstone cliffs bordering the river and running at right angles to it; there are about nine "eyes" distributed along a fairly straight line for a distance of 50 yds. from the river's edge. The springs are sulphuretted and vary in temperature and volume; that furthest from the river has a temperature of 80—90° Fahrenheit and has much the strongest flow and emerges about 20 ft. above the river. Some of the springs are cold. An examination of those near the river's edge was impossible owing to the quickness of the silt, but bubbles indicate that some springs are actually in the river bed. No mineral deposits were in evidence and no implements were recovered from the immediate vicinity.

The sandstone strata lining the river bank below the springs are fairly level, while those above the springs have a slight dip upstream. The small koppies in the neighbourhood of the Homestead show evidence of slight tilting, the small spruit—Badsfontein—apparently following a line of weakness and entering the

river through the cleft, flowing 3 or 4 feet below the level of the springs. This is in marked contrast with the spruit further down-stream flowing over sandstone and entering the river in a series of waterfalls.

Considering all the factors it would appear that the Badsfontein Springs may be due to faulting.

Klipfontein Diamond Diggings.—The diggings are situated about 12 miles down-stream from the Hertzog Bridge. They are remarkable for some peculiar current-bedding in the gravels here. A small gravel koppie was virtually decapitated and a pit sunk into it to a depth of 25 ft. (Fig. 3), exposing a dolerite dyke which was obviously responsible for the phenomena observed. Up to a depth of 20 ft. the gravels are horizontal on both sides of the dyke; above this on the right face, the gravels are basined, while on the opposite face, where there is no dolerite, these strata are distinctly arched. Apparently the dyke formed a partial bar across the river, causing the gravel to be deposited in this peculiar manner.

While the progressive deposits of pebbles, grits and sands above a boulder-bed on the left face might appear to indicate a variation in the river's transporting ability due to a changing climate, that is negatived by the presence of grits of the same age below the boulders on the right face (Fig. 3).

The gravels contain implements of Pre-Stellenbosch, and Stellenbosch types and flake implements simulating the Fauresmith and M.S.A., but no stratigraphical sequence from top to bottom was evident.

Badsfontein Hot Spring.—This spring is situated about 6 miles downstream from Klipfontein, emerging from the upstream side of a dolerite dyke which appears to run at right angles to the river 400 yds. away. The spring is on a fairly extensive 50-ft. terrace, is sulphuretted, does not flow strongly and has a temperature of between 80 and 90 degrees Fahrenheit. No gravels were noticed in the vicinity, but a bank of silt rises to about 70 ft. near the river's edge. The presence of the three hot springs along the valley of the Upper Orange is more than a coincidence and may be interpreted as due to crustal movement. du Toit (1933) has made a simliar observation with regard to the distribution of South African Hot Springs in general.

The Age of the Deposits Above the Hot Springs at Aliwal North.—With a view to dating and correlating the evidence, a further examination was undertaken of the area bounded by the sandstone scarp which rises immediately behind these springs; the adjacent area below the scarp was also examined. The sandstone scarp bordering the springs stands about 300 ft. above the Orange and Kraai Rivers and shows the same tendency to fade into the hillside as the scarps of Oorlogsfontein. Apparently it also represents a fault-scarp, and if that be so, the superficial spreads of material of a somewhat similar nature to that of the

Orange and Kraai River gravels now lying above the scarp, must have been deposited by the river before the scarp was formed.

Small rolled flake implements of an indefinite type, but simulating a crude M.S.A. facies are present in the gravel-spreads and appear to belong to the gravels. Rolled cores and points of undoubted M.S.A. origin are however present in the red sandy soil of the neighbourhood; apart from the rolled nature of the implements, no other evidence was found indicating that these red soils were waterborne.

Implements of a M.S.A. facies were also recovered from the red sandy soil below the scarp and also from a similar deposit which abuts the high level river gravels at one point on the Kraai River, this latter deposit appears to be waterborne, but no exposure showing the sequence of gravels and red sands containing implements has been observed.

Better evidence was yielded by a vertical exposure of current-bedded river grits standing 100-150 ft. above the Kraai River; here the deposits are unmistakably of fluviatile origin. Two artifacts, a core and a blade—unrolled and of a definite M.S.A. form were recovered from the vertical face of the deposit. It then appears possible that implements of a M.S.A. type were the last to be deposited by the rivers before the movement postulated by the writer took place. There is also support for this assumption from the presence of well-rolled implements of Fauresmith type (Fig. 4 Nos. 1, 2 and 3) in a 6-ft. thick consolidated gravel bed, standing only 6-8 ft. above the Kraai River at a point where such a low-lying bed could be expected, i.e. where the Kraai was presumed to have cut across the former Orange River deposits (Fig. 1, and accompanying map of the area. 1945).

The rolled graded series of implements from the high gravels at Oorlogsfontein can in the light of this evidence be presumed to have been deposited by such a river.

Acknowledgments.—The writer is indebted to Dr. A. L. du Toit for his generous help at all times, Mr. C. W. T. Duminy of Cape Town, Councillor Ackermann, Mayor of Aliwal North, and Mr. J. F. G. Kruger, Town Clerk of Aliwal North, and the many farmers, whose assistance was accompanied by their typical hospitality.

REFERENCES.

Du Toit, A. L.: "Crustal Movement as a Factor in the Geographical Evolution of South Africa." *S.A. Geogr. Journal*, **16**: 1-20 (1933.)

Breuil, H.: "Archaic Chipped Pebble and Flake Industries from the Older Gravels of Various Sections of the Vaal Valley." *This Journal*, **40**: 282-4 (1943).

Sohnge, P. G., Visser, D. J. L. and Van Riet Lowe, C.: "The Geology and Archaeology of the Vaal River Basin." Geol. Mem. No. 35. Govt. Printer, Pretoria (1937).

Macfarlane, D. R.: "The Orange River High Level Gravels at Aliwal North in Relation to Crustal Movement and the Stone Age. *This Journal*, **41**: 415-28 (1944).

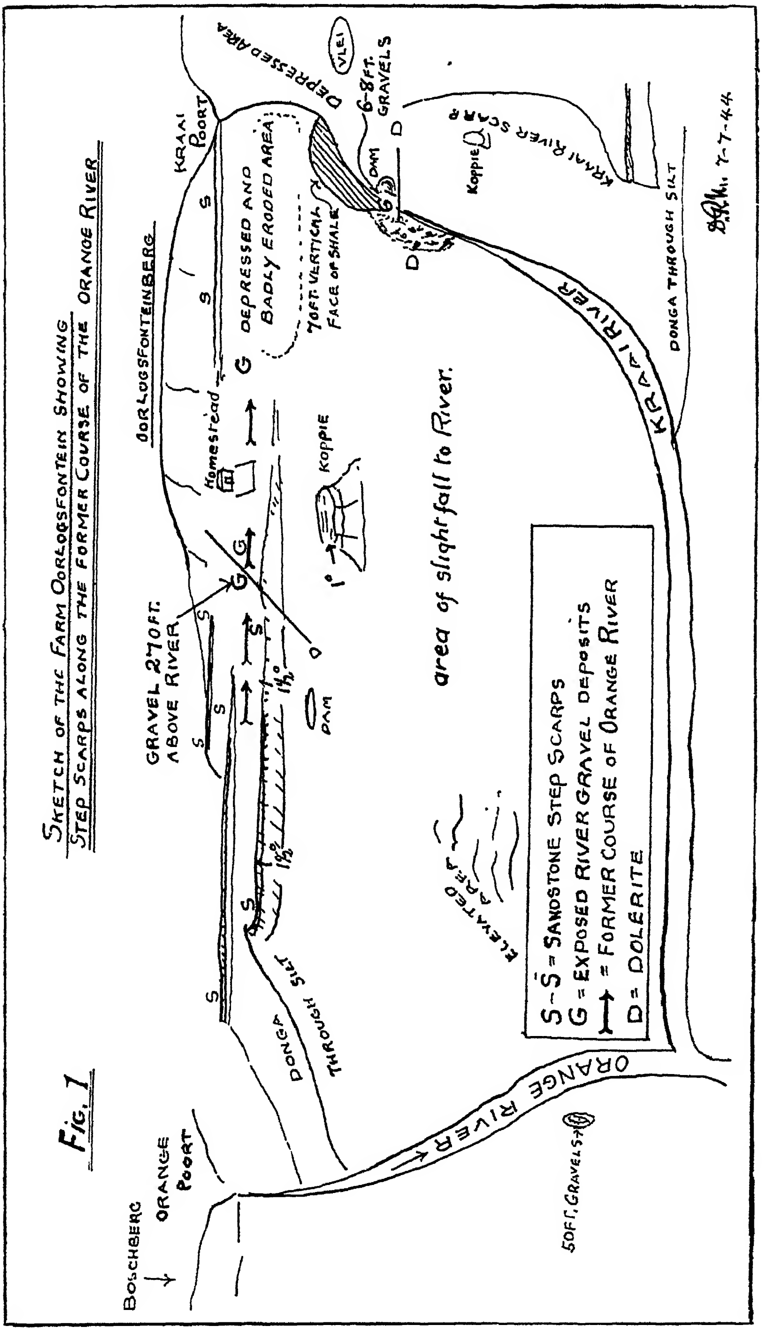


Fig. I
Sketch of the Farm Oorlogsfontein Showing
Step Scarps along the Former Course of the Orange River
Oorlogsfonteinberg
Boschberg
Orange Poort
Kraal Poort
Depressed Area
Vlei
6-8 ft. Gravels
Depressed and Badly Eroded Area
70 ft. Vertical Face of Shale
Gravel 270 ft. Above River
Homestead
Koppie
Dam
area of slight fall to River.
Elevated Area
Donga through Silt
Kraai River
Kraai River Scar
Orange River
50 ft. Gravels
S–S = Sandstone Step Scarps
G = Exposed River Gravel Deposits
= Former Course of Orange River
D = Dolerite
7-7-44

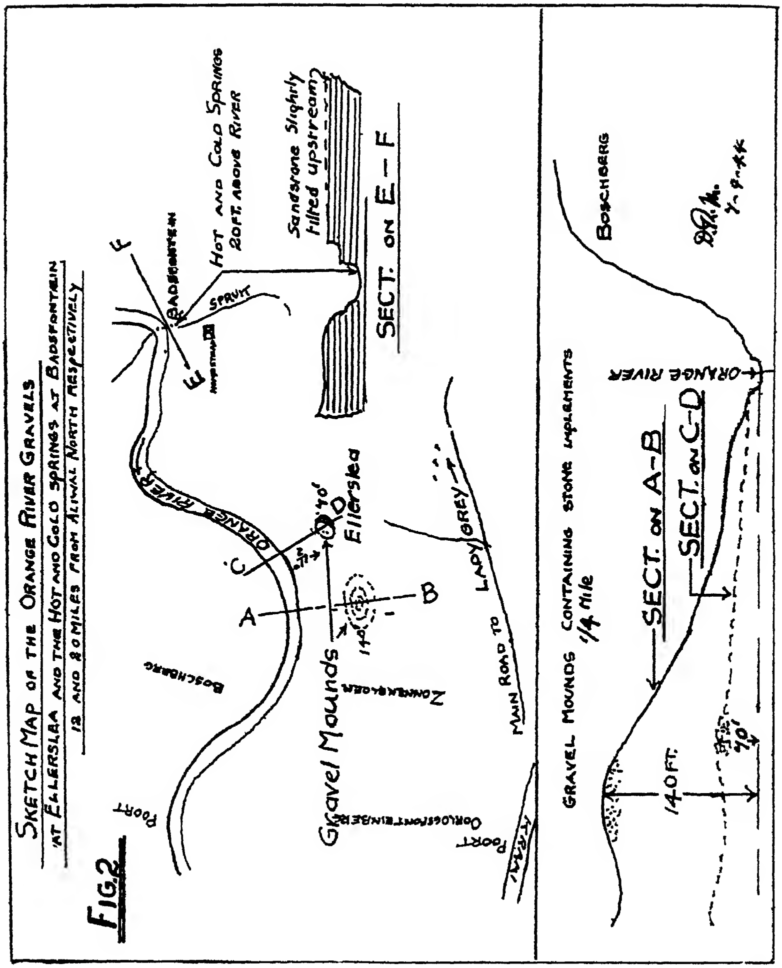
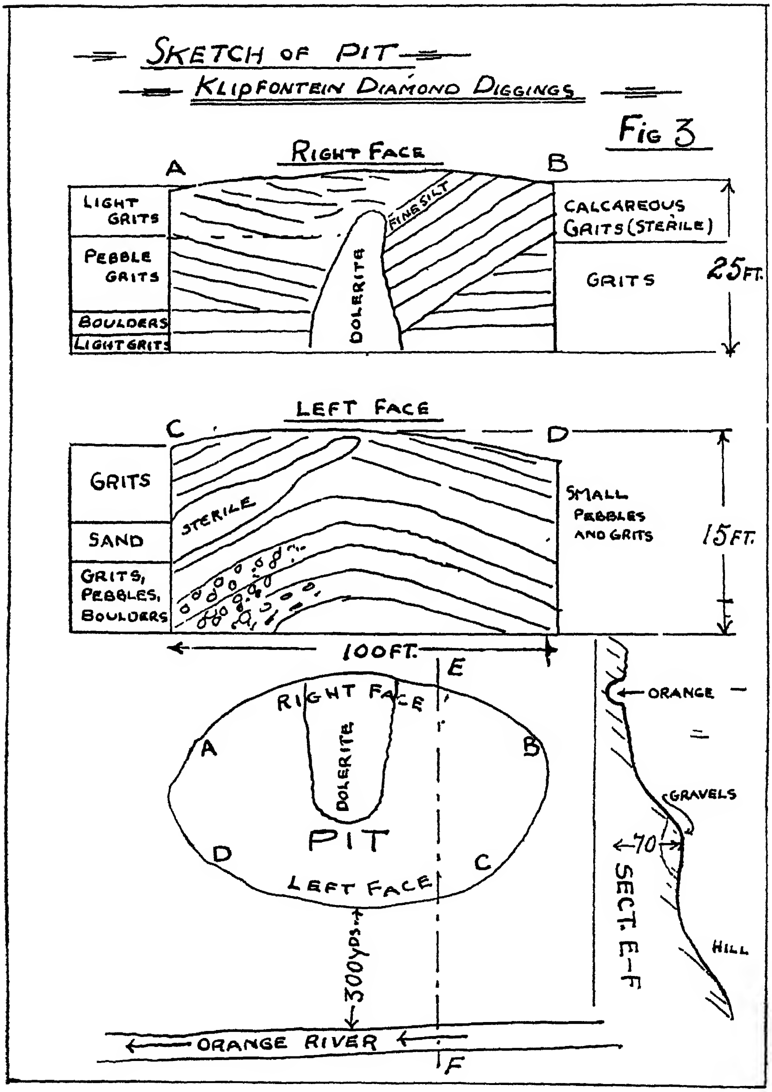


Fig. 2
Sketch Map of the Orange River Gravels
at Ellerslea and the Hot and Cold Springs at Badsfontein
12 and 20 miles from Aliwal North respectively
Hot and Cold Springs
20 ft. above River
Sandstone slightly tilted upstream
Sect. on E – F
Badsfontein
Spruit
Orange River
Boschberg
Poort
Gravel Mounds
Ellerslea
Main Road to Lady Grey
A
B
C
D
E
F
Gravel Mounds containing stone implements
1/4 mile
Sect. on A–B
Sect. on C–D
140 ft.
Orange River
Boschberg



SKETCH OF PIT
KLIPFONTEIN DIAMOND DIGGINGS
FIG 3
RIGHT FACE
A
B
LIGHT GRITS
PEBBLE GRITS
BOULDERS
LIGHT GRITS
FINE SILT
DOLERITE
CALCAREOUS GRITS (STERILE)
GRITS
25 FT.
LEFT FACE
C
D
GRITS
SAND
GRITS, PEBBLES, BOULDERS
STERILE
SMALL PEBBLES AND GRITS
15 FT.
100 FT.
E
RIGHT FACE
DOLERITE
PIT
LEFT FACE
300 YDS.
ORANGE RIVER
F
ORANGE
GRAVELS
70
SECT. E–F
HILL

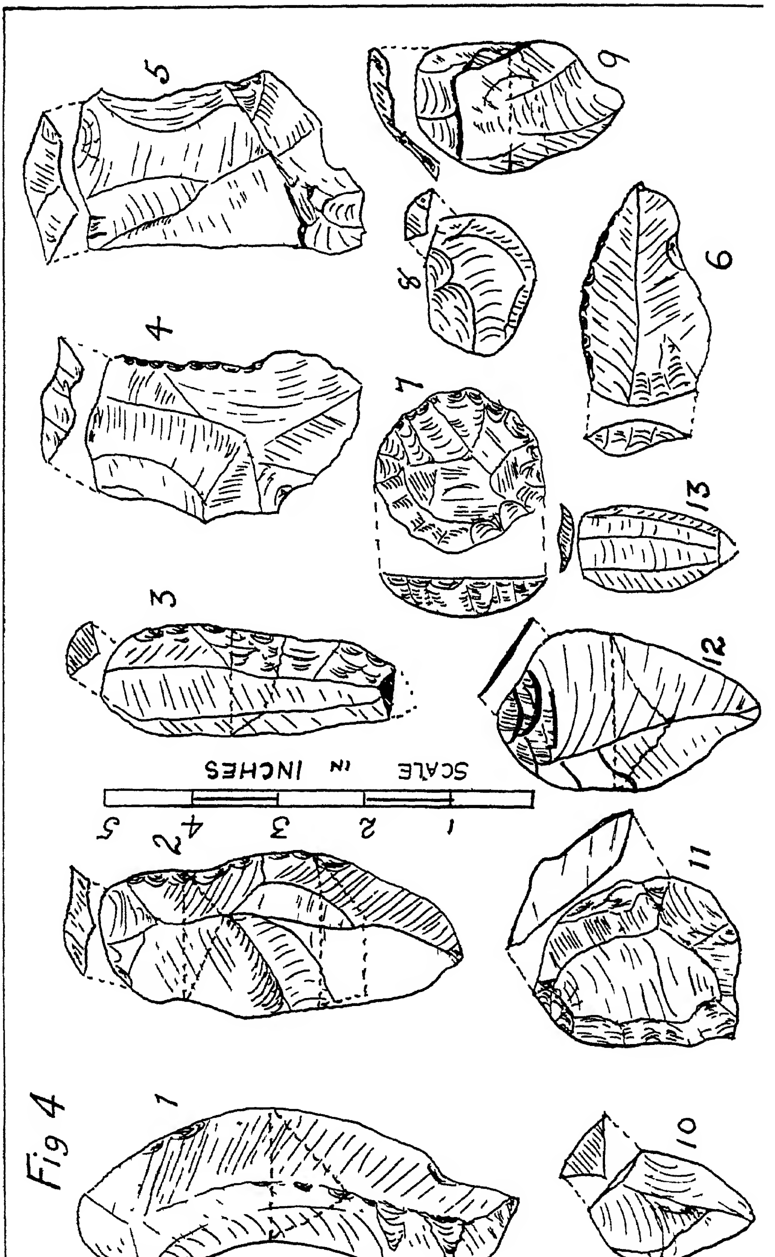


Fig 4
SCALE IN INCHES
1
2
3
4
5

INDEX TO CONTRIBUTORS.

SUBJECT INDEX.